7.8.5 Process Model

Engineering Design File

PROJECT FILE NO. 021052

OU 7-10 Glovebox Excavator Method Process Model

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1.	Title: OU 7-10 Glovebox Excavator Method Process Model
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4.	Summary: This report describes the development, implementation, and results of a dynamic, visually interactive model to simulate the operations for the OU 7-10 Glovebox Excavator Method. Originally, the primary purpose of this model was to provide and support an operational schedule estimate. However, as it evolved, its benefits extended to assisting in evaluating and improving both the design and the operations process. The model has been developed in Extend™, an industrial process modeling software package, developed and marketed by Imagine That! Inc. It is based on the process flows that were developed by a multidisciplinary team comprised of design engineers, systems engineers, specialty engineers, and operations experts. This team also provided inputs for the discrete task durations. Based on the baseline scenario, the model indicates that the duration of normal operations will be about one month. This assumes no emergency or other work-stopping situations arise and it does not include time associated with manually excavating part of the overburden, relocating probes, or sampling the underburden. So, this should not be considered the actual estimation of the full retrieval operations duration.
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	R/A	Typed Name/Organization	Signature	Date
Author		Danny Anderson/Process	Danny L Anderson	7/10/2002
Independent Peer Reviewer	A	Kirt Jamison/Process	[illegible]	7/10/2002
Doc. Owner	A	Mark Borland/Process	Mark Borland	7/10/02
Requestor	Ac	Steve Davies/Project Engineer	Steve Davies	7/11/02
		James Barker/Ops Manager	[illegible]	7-11-02
Doc. Control	Ac	Annie Butters	Annie Butters	8/14/02

6. Distribution: (Name and Mail Stop)	jamison
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ACRONYMS

AMWTF	Advanced Mixed Waste Treatment Facility
EDF	engineering design file
INEEL	Idaho National Engineering Laboratory
OU	operable unit
PVC	polyvinyl chloride
RCS	Retrieval Confinement Structure
WES	Weather Enclosure Structure

OU 7-10 Glovebox Excavator Method Process Model

1. INTRODUCTION

This report describes the development, implementation, and results of a dynamic, visually interactive model to simulate the operations for the OU 7-10 Glovebox Excavator Method. The OU 7-10 Glovebox Excavator Method operations include excavation, retrieval, handling, sampling, packaging, assaying, transportation, and storage of the contents of a portion of Pit 9, at the Department of Energy's Idaho National Engineering and Environmental Laboratory (INEEL), Idaho Falls, Idaho.

1.1 Purpose

Originally, the primary purpose of this model was to provide and support an operational schedule estimate. However, as it evolved, its benefits extended to assisting in evaluating and improving both the design and the operations process.

1.2 Scope

This report describes the development and initial implementation of a dynamic, visually interactive model to simulate the operations for this project. The primary purpose of this model is to provide and support an operational schedule estimate. The model can be enhanced to support optimization of the system design, throughout the design phase, and operations manning and planning, throughout the operations phase of the project. The model has been developed in Extend™ (version 5.0.4), an industrial process modeling software package. A multidisciplinary team comprised of design engineers, systems engineers, specialty engineers, and operations experts jointly developed the operational process and identified initial estimates of individual discrete task durations. A list of team members is provided as Appendix A. The process flow is described in process logic diagrams and associated narratives, which are fully documented in INEEL/EXT-02-00703 (Jamison and Preussner, 2002).

This process then was translated into the Extend™ model. The inputs to the model include material quantities and discrete times or task durations. The model assumes that no emergency or other work-stopping situations will arise and it does not include time for manually excavating part of the overburden, relocating probes, or sampling the underburden. In other words, the model represents continuous, normal, repetitive operations, and provides a prediction of the minimum schedule possible, not the actual anticipated schedule. Time can be added to the front or back end of the schedule prediction for some of these preliminary and follow-on activities.

This EDF describes the following:

1. The assumptions and calculations, upon which inputs are based
2. The baseline set of inputs, both material quantities and individual task times
3. The structure and layout of the model's process
4. The verification and validation measures taken
5. The results or outputs of the model
6. How the model has been used to support various design decisions.

2. MATERIAL QUANTITY ASSUMPTIONS

Material quantities, and their calculated derivations, are officially documented in EDF-3125 (Walsh and Anderson, 2002), as part of the process calculations. Some of these calculations are repeated, unofficially, in the model, and are described in this EDF. The reason for performing calculations again is to allow flexibility within the model for adjusting and comparing various pit configurations and waste inventory scenarios. At the time of publication, quantities and calculations in both EDFs are consistent; however, calculations in the model, as described in this EDF, are not intended to supercede those in the process calculations (EDF-3125).

2.1 Pit Size/Orientation

The excavation pit ground surface is a 145-degree sector of a circle, with a radius of 20 ft (design baseline, INEEL/EXT-01-01512, 2002) (see Figure 1). Overburden is assumed to extend to a depth of 3.5 ft (INEEL/EXT-2000-00403, 2000). The overburden layer walls will be vertical, supported by a shoring box. The waste layer is assumed to be 7.5-ft thick (INEEL/EXT-2000-00403, 2000). In the waste layer, where there will be no shoring box, the angle of repose for the soil and waste is assumed to be 52 degrees (based on informal testing, Craig Bean, INEEL Materials Testing Laboratory, 11/2001). Based on this geometric configuration, the volume of the overburden, before disturbing it, is about 66 yd^3, the volume of the waste layer, before disturbing it, is about 79 yd^3, and a surface area of about 103 ft^2, of underburden, will be exposed for coring/sampling.

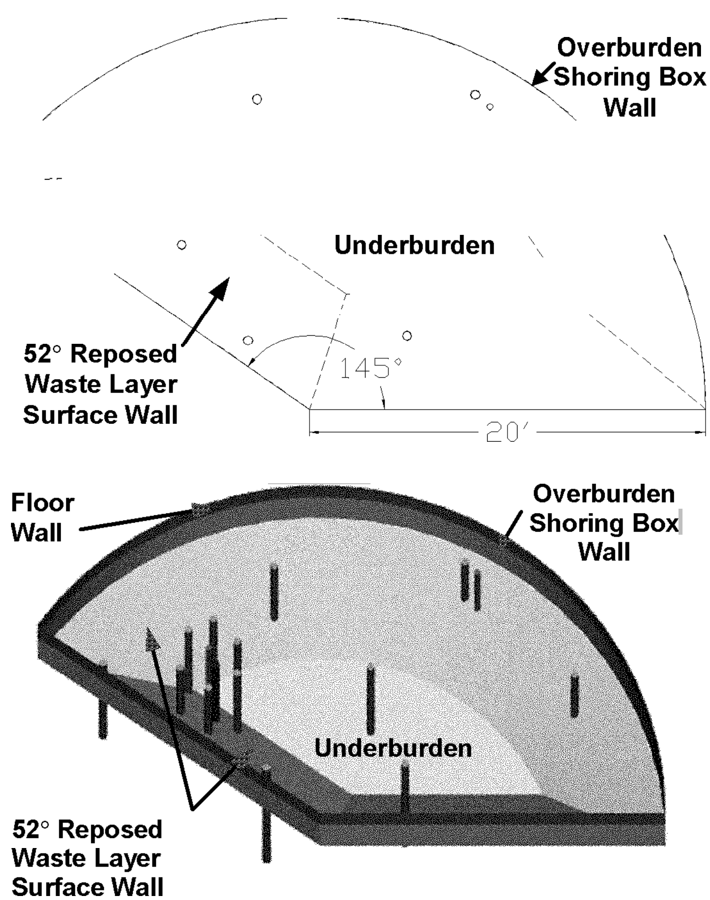


Figure 1. Pit configuration inventory in 40 x 40-ft portion of Pit 9.

A waste inventory has been researched for a 40 x 40-ft^2 portion of Pit 9, which subtends most of the planned fan-shaped excavation pit (see Figure 2). This inventory provides an assumed number of specific types of waste drums, as shown in Table 1 (Einerson and Thomas, 1999). The drums are assumed to be randomly and uniformly distributed in the 7.5-ft-thick waste layer of this 40 x 40-ft^2 area.

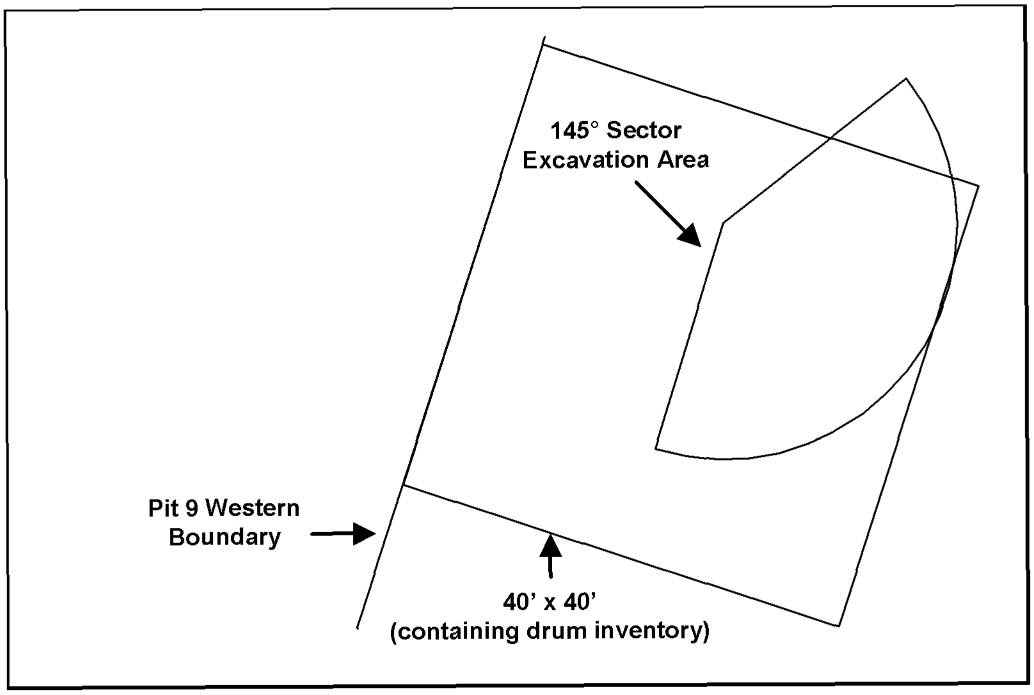


Figure 2. Excavation area overlaying the 40 x 40-ft square.

Table 1. Inventory scaling.

Waste Type / Drum Contents	40' x 40 ft' Inventory	Scaled Inventory
741 Sludge	3 drums	1 drums
742 Sludge	27 drums	5 drums
743 Sludge	379 drums	67 drums
744 Sludge	2 drums	1 drums
745 Sludge	42 drums	8 drums
Graphite	22 drums	4 drums
Combustible debris	260 drums	46 drums
Noncombustible debris	28 drums	5 drums
Empty drums	544 drums	97 drums
Total number of waste drums	763 drums	137 drums

2.2 Overburden Assumptions

Overburden soil, which was placed over the waste zone material as an environmental protection barrier, has to be removed to reach the waste zone material. A manned excavator will remove the overburden. Additional personnel inside the confinement structure will assist with packaging and hand digging around dense probe clusters. Based on probing data, overburden will be retrieved to a depth of 3.5 ft, unless the following conditions exist:

1. The hard-pack zone of overburden is encountered, which generally corresponds with the top of the waste zone

2. Waste zone material is encountered before reaching the 3.5-ft depth

3. Airborne contamination is detected

Overburden soil is packaged into 4 x 4 x 4-ft soil sacks, to within 8 in. of the top. Once disturbed, overburden soil is assumed to expand by 33%, or to 133% of its original value Craig Bean, INEEL Materials Testing Laboratory, 11/2001). The excavator bucket scoops up about 5 ft^3 of expanded soil at a time. Each soil sack holds about 10 scoops. Excavation continues until two soil sacks are filled. The excavator is shut down and the sacks are removed and replaced.

2.3 Waste Assumptions

The waste layer is assumed to be 7.5-ft thick and includes any overburden below a depth of 3.5 ft. The contour shape of the waste layer is complex. In addition to the ground-surface fan shape (sector), the lateral walls are sloped or reposed. As discussed above, the angle of repose is assumed to be 52 degrees. Even if the soil conditions are such that a more vertical surface wall is possible, a sloped surface will be intentionally maintained to prevent sloughing from under the shoring box, in order to maintain a good soil seal around the excavation site. Mathematical integration is required to calculate the volume of this layer, however, integration is approximated by summing the volumes of thin layers (0.001-ft thick). Neither the trapezoidal method nor Simpson's method was needed, since the function that would represent the integration boundary is well behaved at the endpoints. In fact, it is simply a straight-line boundary. The volume of this layer is 79 yd^3. See Section 3, Material Quantity Calculations and Input, for more information on this and other calculations.

The ratio of the volume of the repose-walled, fan-shaped excavation pit's waste layer to the volume of the 40 x 40 x 7.5-ft inventoried waste layer (444 yd^3), is used to scale the drum inventory quantities. This scaling ratio, which is 0.18, is multiplied by each of the drum quantities and the results are rounded up to the nearest integer. The scaled inventory of waste drums for the excavation pit is shown in Table 1.

The drum shells (as opposed to drum contents) are expected to be no longer intact, due to rusting, crushing, and breakage. In the unlikely event that an intact drum is encountered, it will be weighed by the excavator and passed into the glovebox, if it weighs less than 350 lb. If the weight is greater than 350 lb, the drum will be broken with the backhoe bucket, if possible, or will be left in the pit.

The waste from each drum, buried in the pit, is assumed to take up a volume of 6 ft^3 (Clements, 1982). It is assumed that, as the drums decayed, interstitial soil subsided to fill the voids between waste objects. Additional overburden was placed on the subsidence areas to fill up and restore to level conditions. The total scaled number of drums is multiplied by the waste volume per drum and subtracted from the volume of the 7.5-ft-thick waste layer to obtain the volume of interstitial soil.

Waste and interstitial soil is apportioned into drum-volume equivalents. Once disturbed, both soil and waste will expand in volume, with the exception of noncombustible debris, or metals. Interstitial soil, like overburden soil, is assumed to expand by 33%, or to 133% of its original value (Craig Bean, INEEL Materials Testing Laboratory, 11/2001) and waste is assumed to expand by 20%, or to 120% of its original volume (engineering judgment, Mark Borland, 10/2001).

The soil and waste are brought into the gloveboxes, for handling, in a transfer cart that is lined with a tarp-like liner. The cart liners minimize the need to clean the transfer carts and minimize the generation of dust as the soil or waste is moved from the cart into the drum. The drums have a polyvinyl chloride (PVC) bag liner and a hard-walled 90-mil poly liner. A new, lined 55-gal drum will be filled to capacity, but some of the space will be filled by the poly liner, the previous bag's pigtail, the current bag's pigtail, cart liners, and associated air gaps. A drum is assumed to hold 5 ft^3 of expanded waste or soil. The waste and interstitial soil will be retrieved in 2.5 ft^3 scoops (average), after expansion, so that each new drum will hold two scoops of expanded waste or soil. The backhoe bucket can hold slightly more material (approximately 3 ft^3), but the transfer cart size and the operational process will limit the volume. A demonstration was performed verifying that 5 ft^3 of expanded soil and two drum liners can indeed fit into a 55-gal drum (James Dobbins, Glovebox Mockup Facility, 5/2002).

It is assumed that one rusty fragment of each drum shell remains in the pit. The total number of scoops of waste and interstitial soil to be retrieved, after expansion, are calculated and divided by the total number of buried drums, to obtain the ratio n. It is then assumed that every nth scoop contains one of the fragments.

Drum fragments may be packed into either 85-gal drums or 55-gal drums, with 55-gal drums being the preference. However, in the model it is assumed that all drum fragments are packaged into 85-gal drums, rather than the 55-gal drums. It is assumed that the size of the fragments is such that each 85-gal drum will hold six drum fragments (modeling assumption, Danny Anderson, 5/2002).

Noncombustible waste drums are assumed to contain six metal objects (e.g. vent pipes) (modeling assumption, Danny Anderson, 5/2002). With each scoop, three of these metal objects are retrieved. All six of these metal objects will be repackaged into 55-gal or 85-gal drums, along with the drum fragments. Again, in the model, it is assumed that they will be packaged into only 85-gal drums. The number of metal objects that will be packaged into an 85-gal drum is assumed to be equal to the number of drum fragments that will be packaged into an 85-gal drum. In other words, drum fragments and metal waste objects are all assumed to be roughly the same size. (Note that metal debris does not expand, but what was a 55-gal drum of metal is now an 85-gal drum of metal, resulting in an increase in waste volume, in a sense.)

The five sludge types are combined into a single sludge group. Graphite drums may only contain a small amount of actual graphite, but any copackaged waste is considered graphite for material tracking purposes, in the model. So the entire volume of drum contents is classified as graphite. Combustibles consist of papers and plastics (e.g., bottles, anti-C suits, gloves). Interstitial soil is considered waste, because of contact with contaminated waste, and will be processed through the gloveboxes with the waste. Originally, sludge series, interstitial soil, combustible waste, and graphite could and would be copackaged. The model was constructed accordingly. However, after the model was developed, verified, and validated a decision was made to segregate combustibles. The impacts have not been evaluated at this time.

Based on these assumptions, the number of soil sacks and drum-equivalents of expanded soil and waste that will be processed through the model have been calculated. Quantities are shown in Table 2. Quantities of resulting packaged containers are shown in Table 3.

Table 2. Quantities to process through model.

Material Type	Scaled Quantities (from Table 1)	Quantities (Expanded and Packaged)
Overburden soil	N/A	48 soil sacks
Interstitial soil	N/A	346 drum-equivalents
Sludge	82 drums	118 drum-equivalents
Graphite	4 drums	6 drum-equivalents
Combustible debris	46 drums	66 drum-equivalents
Noncombustible debris	5 drums	5 drum-equivalents
Drum fragments	N/A	39 drum-equivalents

Table 3. Filled container quantities.

Material Type / Container Type	Quantities
Overburden soil in sacks	48 soil sacks
Waste in 55-gal drums	536 drums
Metals in 85-gal drums	44 drums

2.4 Sampling Assumptions

Subsamples (aliquots) from as many as 10 carts will be drawn and sequentially placed into the same 250-ml wide-mouth sample container (discussion with Daryl Haefner, 4/2002, and Childs, 2002). This compositing of subsamples will occur in the glovebox and will probably occur over the course of several hours. The sample jar will be kept closed and only opened when an addition is to be made, thereby maintaining a level of sample integrity. Once 10 subsamples have been composited, the jar is closed and designated as a sample. This sample then is removed from the glovebox, placed in a chilled location, and shipped, in a timely manner, to the lab. The lab will homogenize the sample and perform the requested analysis. The sample rate (every *nth* cart) and the number of subsamples per bottle can both be set in the model. In the model, it is assumed that every cart ($n = 1$) is sampled and that 10 subsamples are composited per sample bottle.

2.5 Assay, Transportation, and Storage Assumptions

The model includes a placeholder for assaying drums, but the current process assumes that drums will be sent directly to the Advanced Mixed Waste Treatment Facility (AMWTF), where they will be assayed. If this changes, and the drums must be assayed before sending them to the AMWTF, then a task duration time can be entered into the assay activity block. However, it has been shown that the transportation and storage subprocess is currently balanced with other subprocesses. If the time to transfer a packaged drum from the facility to the AMWTF increases, either by including assay or because travel will take longer, then this subprocess will become the critical path, and the overall schedule estimate will be impacted. This is discussed further in Section 8 of this EDF. This subprocess has not been reviewed by the process development team, and is definitely a weak area in the process model.

3. MATERIAL QUANTITY CALCULATIONS AND INPUTS

The quantities described above are calculated in the model, in a custom block, called Inventory, which is programmed using Imagine That!'s MODL language, a special implementation of the common C++ programming language. The code that calculates the volumes and quantities, used as input to the model, is included at Appendix B.

Initial input parameters and assumptions are entered into the inventory table in the inventory block, and calculations are performed to determine additional parameters for the model. This inventory block screen allows the input of pit geometry parameters, initial inventory values, and other assumptions, and calculates volumes and drum quantities, inserting the drum quantities into the appropriate resource queues in the model. Figure 3 shows this screen. Values with a white background can be entered as inputs and changed. Values with a gray background are calculated values. Values labeled as "Block #" are the identification numbers of other blocks in the model to which the calculated values are to be automatically assigned.

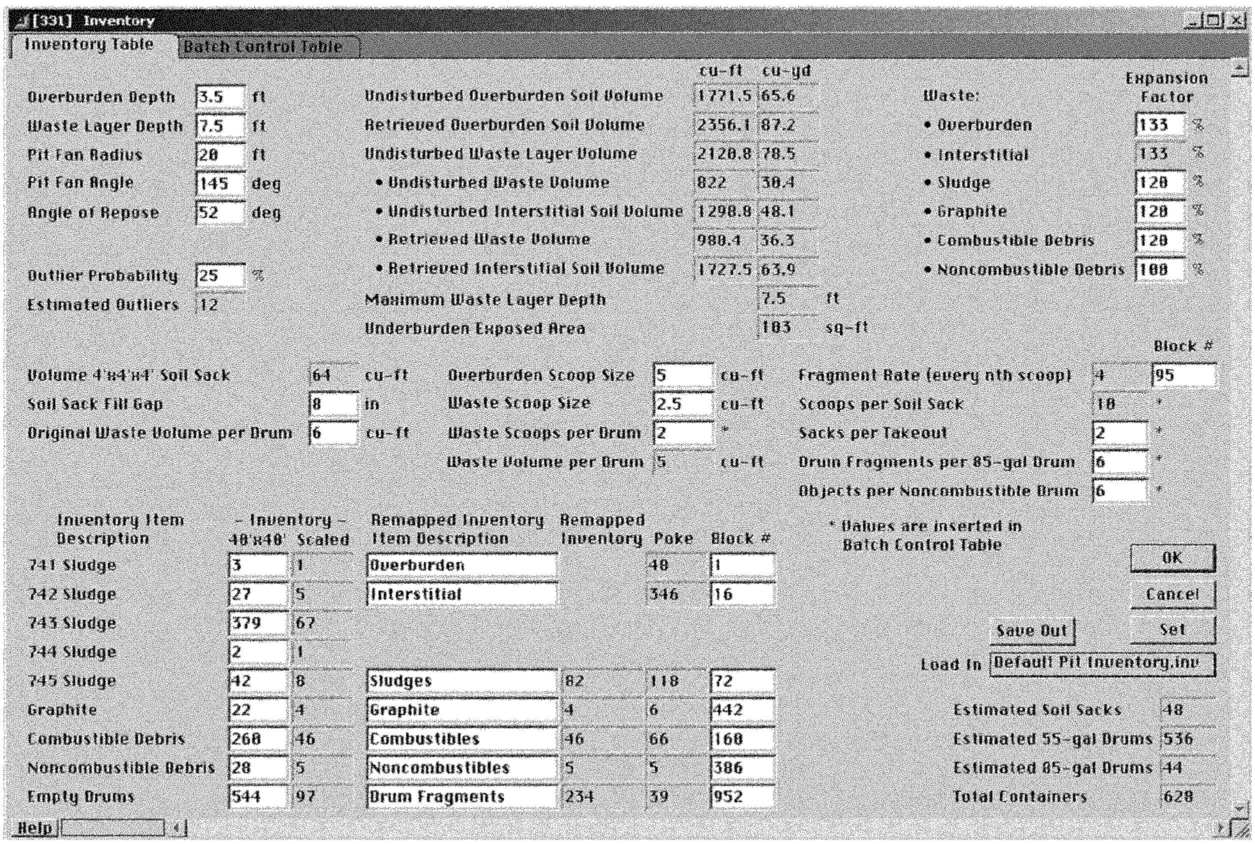
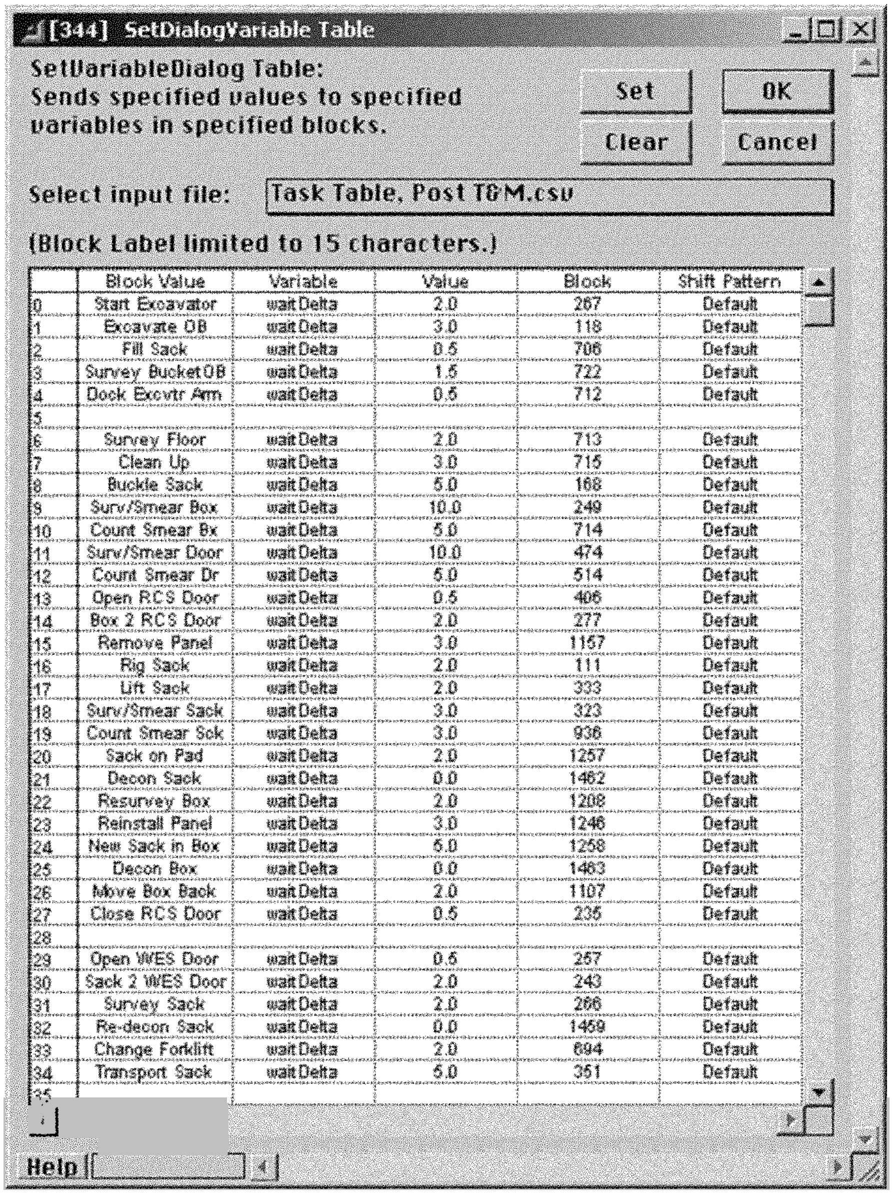


Figure 3. Inventory block (input screen).

4. TIME INPUT

Each distinct task performed as part of the process takes a specified amount of time to complete. Blocks in the model represent these tasks and a time or task duration is entered into the model for each block or task. (In Extend™, these times are called the "waitDelta".) The multidisciplinary team that developed the operational process also identified initial estimates of individual discrete task durations. These times were validated, and adjusted as necessary, through time and motion studies conducted at the glovebox mockup facility at TRA, and through assessment of similar activities conducted and videotaped at the Nevada Test Site. These validation efforts are discussed in more detail later. The individual task times can be input into each applicable machine block in the model or, to save time, they can be input into the SetDialogVariable Table in the Variables Block, as shown in Figure 4. Using the table also reduces the likelihood of input errors. This block also has the ability to import a list of times or task durations from an external file. The column headings are a little confusing. The Block Value column is the 15-character name assigned to the block. The Variable column is the name of the variable in the block that will be assigned a new value. The Value column is the time or duration, in minutes to be assigned. The Block column is the numeric identifier for the block, assigned by Extend™ and used to locate the block. The Shift Pattern column allows assignment of different shifts to each block. Multiple shifts can be defined in the model, but the current baseline model uses the same, default shift for every block (24 hours/day, 7 days/week). The SetDialogVariable Table does not show the full list of times at once and must be scrolled. The full list of durations for the baseline model is shown in Table 4.



	Block Value	Variable	Value	Block	Shift Pattern
0	Start Excavator	waitDelta	2.0	267	Default
1	Excavate OB	waitDelta	3.0	118	Default
2	Fill Sack	waitDelta	0.5	706	Default
3	Survey BucketOB	waitDelta	1.5	722	Default
4	Dock Excvtr Arm	waitDelta	0.5	712	Default
5					
6	Survey Floor	waitDelta	2.0	713	Default
7	Clean Up	waitDelta	3.0	715	Default
8	Buckle Sack	waitDelta	5.0	168	Default
9	Surv/Smear Box	waitDelta	10.0	249	Default
10	Count Smear Bx	waitDelta	5.0	714	Default
11	Surv/Smear Door	waitDelta	10.0	474	Default
12	Count Smear Dr	waitDelta	5.0	514	Default
13	Open RCS Door	waitDelta	0.5	406	Default
14	Box 2 RCS Door	waitDelta	2.0	277	Default
15	Remove Panel	waitDelta	3.0	1157	Default
16	Rig Sack	waitDelta	2.0	111	Default
17	Lift Sack	waitDelta	2.0	333	Default
18	Surv/Smear Sack	waitDelta	3.0	323	Default
19	Count Smear Sck	waitDelta	3.0	936	Default
20	Sack on Pad	waitDelta	2.0	1257	Default
21	Decon Sack	waitDelta	0.0	1462	Default
22	Resurvey Box	waitDelta	2.0	1208	Default
23	Reinstall Panel	waitDelta	3.0	1246	Default
24	New Sack in Box	waitDelta	5.0	1258	Default
25	Decon Box	waitDelta	0.0	1463	Default
26	Move Box Back	waitDelta	2.0	1107	Default
27	Close RCS Door	waitDelta	0.5	235	Default
28					
29	Open WES Door	waitDelta	0.5	257	Default
30	Sack 2 WES Door	waitDelta	2.0	243	Default
31	Survey Sack	waitDelta	2.0	266	Default
32	Re-decon Sack	waitDelta	0.0	1459	Default
33	Change Forklift	waitDelta	2.0	694	Default
34	Transport Sack	waitDelta	5.0	351	Default
35					

Figure 4. Variables block (time input screen)

Table 4. Task durations.

Block Label	Variable	Value (Time)	Block	Shift Pattern	Block Label	Variable	Value (Time)	Block	Shift Pattern
Start Excavator	waitDelta	2.00	267	Default	Move into GB	waitDelta	1.50	671	Default
Excavate OB	waitDelta	3.00	118	Default	Visual Exam	waitDelta	7.00	658	Default
Fill Sack	waitDelta	0.50	706	Default	Resize Fragment	waitDelta	6.25	657	Default
Survey BucketOB	waitDelta	1.50	722	Default	Pack Fragment	waitDelta	1.00	723	Default
Dock Excvtr Arm	waitDelta	0.50	712	Default	Handpack Comb	waitDelta	15.00	737	Default
					Rig to Lift Mtl	waitDelta	2.50	738	Default
Survey Floor	waitDelta	2.00	713	Default	Lift/Txfr Metal	waitDelta	2.00	842	Default
Clean Up	waitDelta	3.00	715	Default	Detach Rigging	waitDelta	2.25	843	Default
Buckle Sack	waitDelta	5.00	168	Default	Get Sample Mtl	waitDelta	0.75	669	Default
Surv/Smear Box	waitDelta	10.00	249	Default	Sample	waitDelta	1.00	670	Default
Count Smear Bx	waitDelta	5.00	714	Default	Bag Out Sample	waitDelta	2.00	804	Default
Surv/Smear Door	waitDelta	10.00	474	Default	Rig Liner	waitDelta	2.50	672	Default
Count Smear Dr	waitDelta	5.00	514	Default	Put in Drum	waitDelta	2.00	674	Default
Open RCS Door	waitDelta	0.50	406	Default	Detach Liner	waitDelta	2.25	719	Default
Box 2 RCS Door	waitDelta	2.00	277	Default	New Cart Liner	waitDelta	2.75	745	Default
Remove Panel	waitDelta	3.00	1157	Default	Decon Equip	waitDelta	6.00	735	Default
Rig Sack	waitDelta	2.00	111	Default	Return Cart	waitDelta	2.50	747	Default
Lift Sack	waitDelta	2.00	333	Default					
Surv/Smear Sack	waitDelta	3.00	323	Default	Cover Port	waitDelta	1.50	371	Default
Count Smear Sck	waitDelta	3.00	936	Default	Enter DLE	waitDelta	2.00	675	Default
Sack on Pad	waitDelta	2.00	1257	Default	Lower & Rotate	waitDelta	0.75	459	Default
Decon Sack	waitDelta	0.00	1462	Default	Seal Sleeve	waitDelta	3.00	460	Default
Resurvey Box	waitDelta	2.00	1208	Default	Deploy Vac	waitDelta	0.25	487	Default
Reinstall Panel	waitDelta	3.00	1246	Default	Cut & Tape	waitDelta	1.25	488	Default
New Sack in Box	waitDelta	5.00	1258	Default	Close/Lock Drum	waitDelta	1.50	461	Default
Decon Box	waitDelta	0.00	1463	Default	Survey Drum/DLE	waitDelta	6.00	462	Default
Move Box Back	waitDelta	2.00	1107	Default	Cnt Drum Smear	waitDelta	6.00	681	Default
Close RCS Door	waitDelta	0.50	235	Default	Drum to Door	waitDelta	2.25	475	Default
					Place New Drum	waitDelta	2.25	478	Default
Open WES Door	waitDelta	0.50	257	Default	Sleeve Clamp 1	waitDelta	6.00	500	Default
Sack 2 WES Door	waitDelta	2.00	243	Default	Discard Pigtail	waitDelta	0.75	476	Default
Survey Sack	waitDelta	2.00	266	Default	Sleeve Clamp 2	waitDelta	1.25	407	Default
Re-decon Sack	waitDelta	0.00	1459	Default	Raise Drum	waitDelta	2.00	477	Default
Change Forklift	waitDelta	2.00	694	Default	Decon Drum/DLE	waitDelta	0.00	686	Default
Transport Sack	waitDelta	5.00	351	Default	Open Tent	waitDelta	1.00	691	Default
					Remove Drum	waitDelta	2.25	479	Default
Prepare Digface	waitDelta	2.00	188	Default	Label Drum	waitDelta	0.50	480	Default
Excavate	waitDelta	1.00	189	Default	Move & Stage	waitDelta	5.00	676	Default
Move to Cart	waitDelta	2.00	726	Default	Open Port	waitDelta	1.50	370	Default
Survey Bucket	waitDelta	2.00	727	Default	Stage CartLiner	waitDelta	5.00	503	Default
Fill Cart	waitDelta	0.50	752	Default					
					Txfr to Assay	waitDelta	0.00	327	Default
					Assay & Label	waitDelta	0.00	328	Default
					Txfr to Storage	waitDelta	15.00	52	Default

5. MODEL STRUCTURE

The model is modular in construction to facilitate adaptations and to enhance readability and understanding. In Extend™, modules are contained in hierarchical blocks. The modules in this model are based on, but not identical to, the subprocesses identified in the process logic diagrams and narratives. They include: (1) the main module, (2) a setup module, to build up a virtual waste pit or queue of waste contents, (3) an excavation and retrieval module, (4) an overburden packaging module, (5) an overburden storage module, (6) a material handling module that is cloned twice (to make three), (7) a container change-out module that is also cloned twice, and (8) a transportation and storage module. Screen shots of these modules are shown in Appendix C.

6. VERIFICATION AND VALIDATION

Verification of a process simulation model involves steps taken to determine and demonstrate that the model functions correctly or, in other words, that it was designed as intended. Validation involves steps taken to determine and demonstrate that the model was designed correctly, and that it adequately represents reality. Throughout the development of the model, hand calculations (i.e., using a calculator, pencil, and paper) were performed and compared with the model outputs. The model was decomposed into individual subprocesses, and each was run to ensure that it behaved and reacted as expected.

The model was also verified through an Excel™ spreadsheet, which represented a simplified static model. Results from both the static model (Excel™) and the dynamic process model (Extend™) were very similar, generally within 5%, and often within 1%. This spreadsheet is shown in Figure 5. Raw time, efficiency time, and productive time are explained in Section 7.

OU 7-10 Glovebox Excavator Method Process Verification Analysis

Per Cycle	Hours			Days
Process	Raw	Efficiency	Productive	Productive
Overburden Excavation	0.13	0.18	0.29	0.01
Overburden Packaging	0.88	1.26	2.02	0.08
Overburden Packaging A1	0.20	0.29	0.46	0.02
Overburden Packaging A2	0.08	0.12	0.19	0.01
Overburden Storage	0.19	0.27	0.44	0.02
Waste Excavation	0.13	0.18	0.29	0.01
Waste Packaging	0.99	1.41	2.26	0.09
Changeout	0.27	0.39	0.62	0.03
Changeout A1	0.24	0.35	0.55	0.02
Changeout A2	0.10	0.14	0.23	0.01
Changeout B1	0.11	0.15	0.25	0.01
Changeout B2	0.15	0.21	0.33	0.01
Transportation & Storage A1	0.00	0.00	0.00	0.00
Transportation & Storage A2	0.00	0.00	0.00	0.00
Transportation & Storage A3	0.25	0.36	0.57	0.02

Totals	Hours			Days
Process	Raw	Efficiency	Productive	Productive
Overburden Excavation	40.0	57.1	91.4	3.8
Overburden Packaging	33.9	48.4	77.4	3.2
Overburden Packaging A1	9.6	13.7	21.9	0.9
Overburden Packaging A2	4.0	5.7	9.1	0.4
Overburden Storage	8.9	12.8	20.4	0.9
Waste Excavation	135.5	193.6	309.7	12.9
Waste Packaging	600.3	857.5	1372.0	57.2
Changeout	157.1	224.4	359.0	15.0
Changeout A1	140.2	200.2	320.4	13.3
Changeout A2	58.0	82.9	132.6	5.5
Changeout B1	62.8	89.8	143.6	6.0
Changeout B2	84.6	120.8	193.3	8.1
Transportation & Storage A1	0.0	0.0	0.0	0.0
Transportation & Storage A2	0.0	0.0	0.0	0.0
Transportation & Storage A3	145.0	207.1	331.4	13.8

Independent Processing Times	
Overburden Retrieval & Packaging Process	8.8 days
Waste Retreival & Packaging Process thru 1 GB	57.2 days
Waste Retreival & Packaging Process thru 3 GBs	19.1 days
Container Change-Out Process thru 1 GB	34.3 days
Container Change-Out Process thru 3 GBs	11.4 days
Transportation & Storage Process	13.8 days
Accounting for Overlapping Processes	
Overburden Retrieval & Packaging Process	8.0 days
Waste Retreival & Packaging Process	19.1 days
Container Change-Out Process	0.1 days
Transportation & Storage Process	0.0 days
Total Time	27.1 days
	0.9 months

Throughput Rate Capabilities	
Soil Sacks per Day	**6.0 sacks/day**
Drums Packaged per Day	30.4 drums/day
Drums Packaged per Day per Glovebox	10.1 dr/dy/gb
Drums Packaged per Shift	15.2 drums/shft
Drums Packaged per Shift per Glovebox	5.1 dr/shft/gb
Drums Changed Out per Day	50.7 drums/day
Drums Changed Out per Day per Glovebox	16.9 dr/dy/gb
Drums Changed Out per Shift	25.4 drums/shift
Drums Changed Out per Shift per Glovebox	8.5 dr/shft/gb
Drums Fully Processed per Day	**30.2 drums/day**
Drums Fully Processed per Day per Glovebox	**10.1 dr/dy/gb**
Drums Fully Processed per Shift	**15.1 drums/shift**
Drums Fully Processed per Shift per Glovebox	**5.0 dr/shft/gb**

Figure 5. Verification of model output.

Precalculations performed within the model, to determine volumetric inputs, as described earlier and shown in Figure 3, were also verified in an Excel™ spreadsheet. This spreadsheet is shown in Figure 6. Both sets of calculations compared accurately with each other and with the official Process Calculations documented in EDF-3125 (Walsh and Anderson, 2002). Integration of the waste layer volume, for the spreadsheet, was performed in an Excel™ macro. The Visual Basic™ code for the macro is included in Appendix B.

OU 7-10 Pit Definition, Waste Inventory, and Calculations

Pit Geometry

Pit Radius	20	ft
Pit Fan Angle	145	deg
Overburden Depth	3.5	ft
Waste/Interstitial Depth	7.5	ft
Underburden Depth	3.0	ft
Total Depth	14.0 ft	

Maximum Waste Layer Depth	7.5 ft
Waste Layer Wall Angle of Repose	52.0 deg
Pit Surface Area	506.1 ft^2
Underburden Area Exposed	103.0 ft^2

Volumes

Undisturbed Overburden Volume	1771.5 ft^3	65.6 yd^3
Retrieved Overburden Volume	2356.1 ft^3	87.3 yd^3
Undisturbed Waste Layer Volume	2120.9 ft^3	78.6 yd^3
Undisturbed Waste Volume	822.0 ft^3	30.4 yd^3
Undisturbed Interstitial Soil Volume	1298.9 ft^3	48.1 yd^3
Retrieved Waste Volume	980.4 ft^3	36.3 yd^3
Retrieved Interstitial Soil Volume	1727.5 ft^3	64.0 yd^3

Miscellaneous Parameters

Overburden Scoop Size	5.0	ft^3
Volume of 4'x4'x4' Soil Sack	64	ft^3
Fill Gap at Top of Soil Sack	8	in
Filled Volumed of Overburden Sack	53.3	ft^3
Overburden Scoops per Sack	10	
Original Waste Volume per Drum	6.0	ft^3
Waste Scoop Size	2.5	ft^3
Waste Scoops per Drum	2	
Waste Volume per Drum	5.0	ft^3
Fragment Rate (every nth scoop)	4	
Drum Fragments per 85-gal Drum	6	
Objects per Noncombustible Drum	6	
Sample Rate (every nth cart)	1	

Waste Inventory	40'x40'	Scaled
741 Sludge	3 drums	1 drums
742 Sludge	27 drums	5 drums
743 Sludge	379 drums	67 drums
744 Sludge	2 drums	1 drums
745 Sludge	42 drums	8 drums
Graphite	22 drums	4 drums
Combustible Debris	260 drums	46 drums
Noncombustible Debris	28 drums	5 drums
Empty Drums	544 drums	97 drums
Total Waste Drums	1307 drums	234 drums

Packaging	ExpFact	Packaged
Overburden Soil	133%	48 sacks
Interstitial Soil	133%	346 drums
Sludges	120%	118 drums
Graphite	120%	6 drums
Combustuble Debris	120%	66 drums
Noncombustible Debris	100%	5 drums

Analysis Parameters

Total scoops of overburden	472 scoops
Sacks removed as group	3 sacks/cycle
Overburden packaging & storage cycles	16 cycles
Number of gloveboxes	3 gloveboxes
Total scoops of waste & interstitial soil	1084 scoops

Container Count

Overburden Soil Sacks	48 sacks
55-gal Waste Drums	536 55-gal drums
85-gal Metals Drums	44 85-gal drums
Total Containers	628 containers

Debris Outliers

Debris Outlier Probability	25%
Debris Outliers	12 items

Figure 6. Verification of material quantity calculations.

Some initial estimates of individual tasks times were based on a time-coded video of similar glovebox and drum change-out activities performed at the Nevada Test Site. By using such a real world source for time estimates, validation activities became an integral part of this effort from the start. The timesheet transcript is included in Appendix D (Table D-1). The working group then modified these estimates based on local operational experience and engineering judgement. Some of these times then were validated through time and motion studies at a glovebox mockup facility. This timesheet transcript, from the mockup testing, is also included in Appendix D (Table D-2). As a result of the validation effort, in the form of these time and motion studies, some of the individual time estimates were modified, resulting in a 20% increase to the overall schedule estimate.

7. RESULTS (MODEL OUTPUTS)

Based on the baseline scenario, the model indicates that the duration of normal operations will be about one month. This assumes no emergency or other work-stopping situations arise and it does not include time associated with manually excavating part of the overburden, transition to and preparation for waste retrieval, relocating probes, or sampling the underburden. So, this schedule prediction is not comprehensive and should not be considered the total estimate of the operations duration. Also, if many intact drums are encountered, contrary to current assumptions, the schedule will lengthen considerably due to time-consuming resizing activities.

This schedule prediction includes a 70% efficiency factor (per Bob Miklos, 9/2001, and Jeff Bryan, 1/2002), to account for suiting up, meals, breaks, shift change activities, and a few incidental activities that do not directly result in immediate retrieval of overburden or waste (see Figure 7). It also includes a proficiency algorithm (currently, a step function), to represent a learning curve. It is assumed that the activities in the first 60% of the retrieval operations will take twice as long as in the last 40% of the effort (per Bill Lonergan, 10/2001).

TASK	Duration (Minutes)	Cum. Minutes	Shift Time	
			Hrs.	Min.
Arrive at RWMC Ops Bldg (WMF-637)	0	0	0	0
Walk (700') to PPE/Shower Trailer, with 2 min. for queue and badge touch	6	6	0	6
Clothes change	6	12	0	12
Walk (45') to Field Operations Building (WMF-646) for POD	1	13	0	13
Morning Stretch	10	23	0	23
Plan of Day Meeting (including safety talk, work assignments, tailgate training)	20	43	0	43
Walk (45') to PPE/Shower Trailer	1	44	0	44
Don double set of Anti-Cs	15	59	0	59
Walk (445') to WES, with 3 min. for queue and PCM survey	6	65	1	5
Work time	**85**	150	2	30
Doff double set of Anti-Cs	5	155	2	35
Walk (400') to FOB, with 3 min. for queue and PCM survey	6	161	2	41
Break	10	171	2	51
Walk (45') to PPE/Shower Trailer	1	172	2	52
Don double set of Anti-Cs	15	187	3	7
Walk (445') to WES, with 3 min. for queue and PCM survey	6	193	3	13
Work time	**107**	300	5	0
Doff double set of Anti-Cs	5	305	5	5
Walk (1000') to RWMC Ops Bldg (WMF-637), with 3 min queue and PCM survey	9	314	5	14
Lunch Break	30	344	5	44
Walk (700') to PPE/Shower Trailer	4	348	5	48
Don double set of Anti-Cs	15	363	6	3
Walk (445') to WES, with 3 min. for queue and PCM survey	6	369	6	9
Work time	**111**	480	8	0
Doff double set of Anti-Cs	5	485	8	5
Walk (400') to FOB, with 3 min. for queue and PCM survey	6	491	8	11
Break	10	501	8	21
Walk (45') to PPE/Shower Trailer	1	502	8	22
Don double set of Anti-Cs	15	517	8	37
Walk (445') to WES, with 3 min. for queue and PCM survey	6	523	8	43
Work time	**77**	600	10	0
Doff double set of Anti-Cs	5	605	10	5
Walk (1000') to RWMC Ops Bldg (WMF-637), with 3 min queue and PCM survey	9	614	10	14
Dinner Break	30	644	10	44
Walk (700') to PPE/Shower Trailer	4	648	10	48
Don double set of Anti-Cs	15	663	11	3
Walk (445') to WES, with 3 min. for queue and PCM survey	6	669	11	9
Work time	**26**	695	11	35
Doff double set of Anti-Cs	5	700	11	40
Walk (445') to PPE/Shower Trailer, with 3 min. for queue and PCM survey	6	706	11	46
Shower and Clothes Change	10	716	11	56
Walk (700') to RWMC Ops Bldg (WMF-637)	4	720	12	0

1/RF = Efficiency Factor
RF = Realization Factor

	RF	1/RF
Overburden Retrieval	1.77	0.56
Waste Retrieval	1.41	0.71
Weighted Average	1.46	0.68

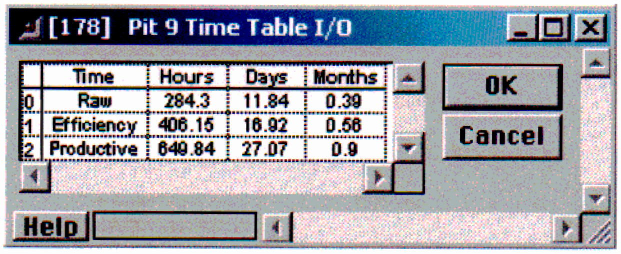
RF = Shift Length / Work Time
1/RF = Work Time / Shift Length

Efficiency Factor = 0.68

Figure 7. Calculation/Verification of Efficiency Factor.

To simplify the implementation of these schedule adjustments, the efficiency factor and the learning curve have been applied to the overall schedule duration reported at the end of a model run, rather than to every individual activity, before running the model. However, a model run was performed in which the efficiency factor and learning curve were applied to each individual activity before running the model and the results were the same, indicating that the simplified implementation was valid.

The model reports the predicted schedule duration in three different time-types: raw time, efficiency time, and productive time. Raw time is the model run time, determined by the clock and the shift pattern. Efficiency time is the raw time divided by the efficiency factor. Productive time is the time that results when the learning curve is applied to the efficiency time. The times reported by the baseline model are shown in Figure 8. A graph showing the completion of processing of soil sacks and drums is shown in Figure 9.



	Time	Hours	Days	Months
0	Raw	284.3	11.84	0.39
1	Efficiency	406.15	16.92	0.56
2	Productive	649.84	27.07	0.9

Figure 8. Operations times reported by baseline model.

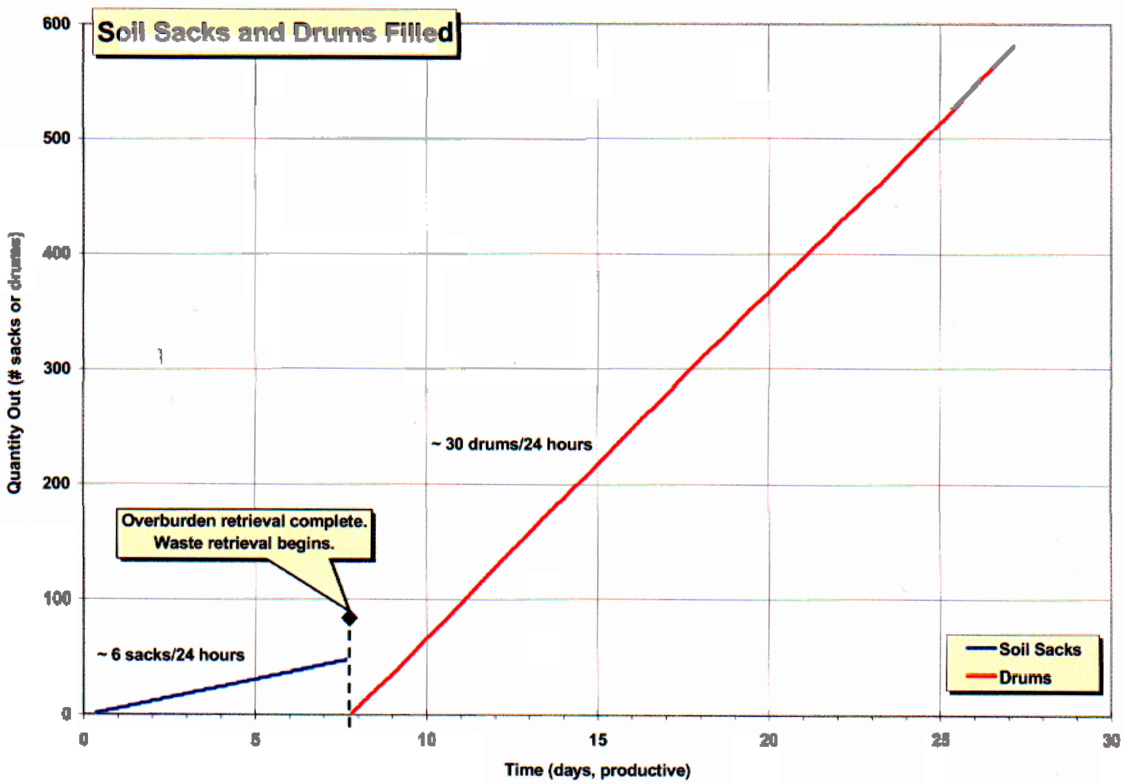


Figure 9. Time-based graph of process-completed soil sacks and drums.

8. APPLICATIONS AND USES

The model has proven very useful to the design team and the process development team. To date, the model has supported the project in the following ways:

1. Initial Schedule Estimate. During the conceptual design phase, the model provided an initial prediction of how long retrieval operations would take, based on the conceptual-level process steps. This schedule duration also was used to estimate the cost of operations. The schedule duration was estimated at 2.4 months.

2. Number of Gloveboxes. The model was used to compare the schedule for two, three, and four gloveboxes. It demonstrated that three gloveboxes, rather than two, would noticeably shorten the schedule (by 33%), but a fourth glovebox would have minimal or no impact, due to a shift in the critical path to other subsystems. See EDF-2081 (Jamison, 2002) for more detail.

3. Number of Soil Sacks. During process development, the process team questioned whether sufficient space existed in the Retrieval Confinement Structure (RCS) to position and maneuver three soil boxes (which support the soil sacks), at the same time. Discussions led to the possibility of using only two soil sacks, or perhaps even one, rather than three, but concerns were raised about impacting the schedule, because operations are shut down while the confinement door is open for removing the soil sacks. The model demonstrated that processing two soil sacks at a time, rather than three, would have minimal impact on the overall schedule. More shutdown periods occurred, increasing from 16 to 24, but the shutdown time was reduced because there was one less sack to handle. Handling two soil sacks at a time, rather than three, only increased the overall schedule by about 4 hours. Handling one soil sack, rather than three, increased the number of shutdowns to 48 and increased the schedule by about 26 hrs.

   Two soil box mockups were constructed and placed in a taped-off area, and maneuvered with pallet jacks, to demonstrate that sufficient room for two existed. (It became clear there was definitely not enough room for three boxes.) Activities were timed to confirm model estimates. As a result of the mockup work and schedule impact assessment, using the model, the use of two boxes was determined to be the optimum process.

4. Location of Soil Sack Handling. While the optimum number of soil sacks was being investigated, the process team also considered the best location to handle the filled soil sacks. Two options existed. The original plan entailed removing all of the filled boxes (three, at the time) from inside the RCS, and bringing them into the Weather Enclosure Structure (WES) buffer area. A second set of boxes were to be sent into the RCS, and the RCS would be closed again so that operations could resume. While overburden excavation proceeded in the RCS, the filled soil sacks, in the WES, were removed from their boxes. A second plan involved leaving the filled boxes in the RCS, but moving them to the door, and removing the soil sacks from the boxes, through the door. This reduced the need for the extra set of boxes, and for space to store and exchange the boxes. The process team identified specific handling steps for each option and estimated times for each step. The model was used to compare the two processes, and indicated that the second option, leaving the boxes in the RCS, saved time. Because this option also brought increased efficiency in surveying, and decreased the likelihood of spreading contamination, this option was selected and the baseline process was modified accordingly.

5. Number of Scoops in Each Drum Versus Scoop Size. Originally, it was estimated that each drum could hold 6 ft^3 of soil or waste, or two cartloads of 3 ft^3 each. As work at the glovebox mockup facility proceeded, it become evident that the transfer cart liners restricted drum packaging

volume so that only 5 ft^3 could fit into a drum, with two cart liners. This meant an increase in the number of filled drums, causing the process team and management to be concerned about schedule impacts. As shown in Table 5, the model demonstrated that filling 536 drums with two scoops of 2.5 ft^3 each would take about two days longer than filling 447 drums with two scoops of 3.0 ft^3 each. The current baseline assumption, as stated above, is two scoops of 2.5 ft^3 each, per 55-gal drum, to fill 536 drums.

Table 5. Comparison of times for drum filling options.

# Scoops	Scoop Size (ft^3)	Schedule (days)	# Drums
2	3.0	24.9	447
2	2.5	27.1	536
2	2.0	31.0	670

6. Glovebox Design Alternatives. After the conceptual design report was issued, concerns were raised about selecting the optimum glovebox design. Four alternatives to the conceptual design were proposed, to enhance ergonomics and support human factors. A trade study was performed to weigh the human factors against cost and schedule. Because each design impacted the process in different ways, the model was used to compare the schedules associated with the four different glovebox designs. The model indicated that among four alternative glovebox designs, the greatest reduction in schedule would be about 13%. The alternative with the shortest schedule, involving a continuous platform and three colocated drum load-out ports, was selected, though not solely because of schedule. (See Appendix E for more detail.)

7. Critical Path. The model was used to determine the critical path. As the design and the process evolved, the model was used to determine if a shift occurred in critical path from one subsystem or subprocess to another. Generally, the critical path was, and still is, the material handling process, or glovebox operations. But, the model has demonstrated that the current process is well balanced, and the critical path shifts easily to the transportation and storage process, if assaying the drums is included in the process or if transportation takes even a few minutes longer than currently estimated.

8. Drum Assay. The baseline process assumes that drums will not be assayed as part of this project. Rather, they will be sent directly and quickly to AMWTF, where they will be assayed. Because of AMWTF permitting issues, concerns have arisen that the project may have to assay drums before sending them to AMWTF. Project management requested an assessment of the schedule impacts associated with this potential change. The model was used to assess the impacts of assaying the drums before transportation, rather than sending the drums directly to AMWTF for assay. An Excel™ spreadsheet was created to provide a rough estimate of the schedule impacts, as a function of assay time (including added transportation time). A plot of the predicted time impacts is shown in Figure 10. It indicates that assay duration must be less than 20 minutes to have no impact on the schedule. If each drum takes 30 minutes (raw time) to assay and another 5 minutes (raw time) for additional transportation and handling at the assay station, then the schedule could increase by up to 15 days (productive time). When these times were entered into the Extend™ model, which allows for parallel processing, the model indicated a schedule extension of about 8.5 days. This impact, demonstrating extreme sensitivity, occurs because the transportation and storage process is well matched to the current critical path process (material handling in the gloveboxes). In fact, simply increasing transportation time by just 5 minutes (raw time), from 15

minutes to 20 minutes, increases the schedule by nearly 4 days (productive time), without even including any assay time. Furthermore, the model showed that schedule was not the only impact. A queue was added to the model to keep track of how many drums would be backed up while waiting for transportation to AMWTF, due to the assay delay. A stockpile of 177 drums resulted, which would require a significant amount of temporary storage space. A decision was made to more rigorously pursue having AMWTF do the assay, while contingency planning for lease of an assay station.

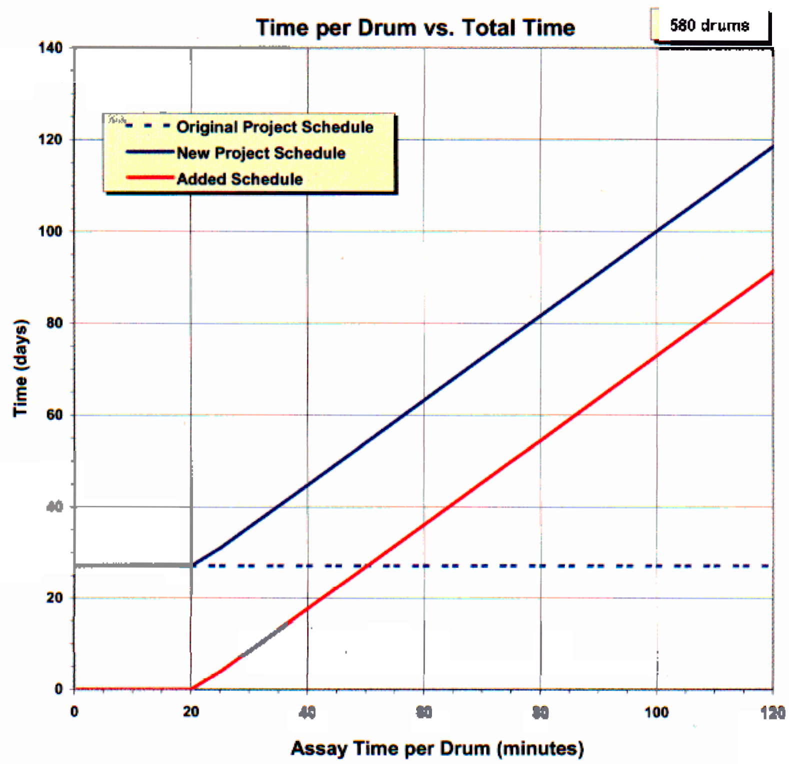


Figure 10. Impacts of lengthened transportation and storage (including assay of drums).

9. Excavator Utilization. Maintenance requirements for the excavator would depend on how long and how often the excavator ran. The model was used to determine the utilization of the excavator (percent of time operating), to establish maintenance parameters. Assuming that shifts operate 24 hrs per day, 7 days per week, at 100% efficiency (nonstop work), the excavator is actually performing process functions 75% of the time, during waste retrieval. It is down only 25% of the time, waiting for an opportunity to proceed, because of glovebox backlog. However, a 70% efficiency factor, rather than 100%, means the excavator is down, along with the rest of the system, for 30% of the operations duration. So, the 75% operating time (or 25% down time) mentioned above is based only on the time that the rest of the system is operating. It was concluded that maintenance and refueling would not affect the schedule, and maintenance requirements were set accordingly.

10. Nitrate Sampling. The original scope of work included collecting composite samples as described in Section 1.5. Collecting additional biased samples, to support nitrate analysis, was proposed. In addition to the planned composite sampling, each cart would have an additional sample collected and placed in another bottle, separate from the original sample, for nitrate analysis. The model was used to assess the schedule impacts associated with doing additional sampling. Incorporating

nitrate sampling into the process model was accomplished easily without modifying the baseline structure, by changing three activity times, as shown in Table 6. When these times were changed in the process model, the overall process time estimate increased by 0.6 to 0.9 days. This schedule change was used then to estimate a cost impact of about $90K for 0.6 days or $135K for 0.9 days ($150K per day). It was decided that nitrate sampling would not be performed on every cartload. See EDF-2303 (Childs, 2002) for more detail.

Table 6. Time adjustments in the model, for nitrate sampling.

Applicable Process Step	Baseline Times (minutes)	Nitrate Sampling (minutes)	Combined (minutes)
Get sampling materials	0.75	0.75	1.5
Collect sample	1	1	2
Bag out sample bottle	2	4	6

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Appendix A

Process Development Team

Appendix A

Process Development Team

Name	Organization/Role	Phone	E-mail
Allred, Matt	Ops, Procedures	6-6294	MALLRED
Anderson, Danny	Process Modeler	6-0863	ANDEDL
Banaee, Jila	Sampling	6-7463	JB6
Barker, Jim	Operations	6-3432	BARKJW
Behrens, Dave	Construction	6-0555	DSB
Bryan, Jeff	Industrial Engineer	6-1899	BRYANJD
Borland, Mark	Process Lead	6-3897	BORLMW
Burton, Brent	Environmental	6-8695	BTB
Carpenedo, Bob	Design	6-1063	EDO
Childs, Kim	Chem. Eng.	6-3261	KCHILDS
Conley, Dennis	Operations	6-4029	DC3
Cresap, Dale	Design	6-8968	DCRESAP
Davies, Steve	Project Eng.	6-4789	SDV
Dicken, Mike	HLW Mgmt	6-1085	DICKTM
Dunihoo, Ramona	SE, Ops	6-5231	RD8
Fluke, Michelle	Ops, Procedures	6-0141	FLUKMA
Gerard, KC	Security	6-0453	GERARDKC
Godfrey, Steve	Ops	6-2564	GODFSD
Haefner, Daryl	DQO/FSP/AMWTF Interface	6-0825	DH8
Helm, Brent	Design Lead	6-8056	BXH
Herbert, Leo	QA	6-7011	HERBRL
Horne, Rick	RadCon	6-5318	HRW
Jamison, Kirt	PE/SE	6-1326	JAMIRK
Jensen, Scott	CE	6-0544	SAJ5
Johnson, Darin	Construction	6-8982	JOHNDR
Larson, Tom	Design	6-5579	NLD
Lopez, Daryl	Design	6-9020	PEZ
McIlwain, Beth	DQO/SAP	6-2537	MCI2
Morris, Virgil	Construction	6-4581	MORRVR
Nickelson, Dave	AMWTF I/F	6-9061	DFN
Peatross, Rod	Safety Analysis	6-8575	TRO
Preussnar, Brian	Design	6-7567	PREUBD
Roege, Paul	Ops Engineering	6-6093	ROEGPE
Ross, Maurice	Remote Eng.	6-4327	MJR1
Sentieri, Paul	Criticality	6-9595	PIS
Snyder, Dale	Operations	6-4773	SNYDDE
Tripp, Julie	R&D	6-3876	JTR1
Walsh, Stephanie	Design	6-5182	WALKSS
Wooley, Kelly	Safety	6-4731/6-2552	WLY

Appendix B

Source Code for Material Quantity Calculations

Source Code for Material Quantity Calculations

MODL™ Code in Extend™ (C++)

```
Procedure SetValues()
{

//*********** Begin Pit Geometry Calculations to Get Volumes ******************

UndisturbedOverburdenVolume = ((PI * FanRadius^2) * OverburdenDepth) * (FanAngleDeg / 360);

//Convert degrees to radians
FanAngle=FanAngleDeg*(PI/180);
AngleRepose=AngleReposeDeg*(PI/180);

//Set maximum depth reached (MaxDepth), based on angle of repose.
//May not reach bottom of waste layer if angle of repose is too shallow.
If (FanRadius-2*WasteThickness/Tan(AngleRepose)<0)
        { MaxDepth=Tan(AngleRepose)*FanRadius/2; }
else
        { MaxDepth = WasteThickness; }

//"Integrate" (i.e., partition and sum) waste layer shape to get volume
Area = 0;
IntegratedVolumeWasteLayer = 0;
dh = 0.001;
for (HH=0; HH<MaxDepth/dh; HH++)
        {
        h = HH * dh;
        a = h / (Tan(AngleRepose)*Sin(FanAngle/2));
        c = FanRadius - h / Tan(AngleRepose);
        X = (a / c) * Sin(FanAngle / 2);
        E = FanAngle - 2 * Atan(X / Sqrt(-X * X + 1)); // Asin(X) = Atan(X / Sqrt(-X * X + 1))
        Area = ((c^2) / 2) * (Sin(FanAngle) * (1 - Cos(E)) / (1 - Cos(FanAngle)) + (E - Sin(E)));
        IntegratedVolumeWasteLayer = IntegratedVolumeWasteLayer + dh * Area;
        }
If (MaxDepth < WasteThickness) { Area = 0; }

Volume40x40 = (40^2) * WasteThickness;

//Calculate scale factor from 40'x40' to actual volume of repose-sided Fan
If (IntegratedVolumeWasteLayer<>0)
{ScaleFactor = IntegratedVolumeWasteLayer / Volume40x40;}
else {ScaleFactor = 0;}

//************* End Pit Geometry Calcs to Get Volumes ******************

//Overburden Calcs
RetrievedOverburdenVolume = UndisturbedOverburdenVolume * SoilExpansionFactor/100;
TotalOverburdenScoops = Ceil(RetrievedOverburdenVolume / OverburdenScoopSize);
VolumeSoilSack = 64;
SackFillFact = (4.00 * 4.00 * (4.00 - FillGap / 12.00)) / VolumeSoilSack;
EffectiveVolumeSoilSack = VolumeSoilSack * SackFillFact;
ScoopsPerSack=Floor(EffectiveVolumeSoilSack/OverburdenScoopSize);
OverburdenSoilSacks = Ceil(TotalOverburdenScoops / ScoopsPerSack);

//Scale 40'x40' volume to actual volume and calculate drum quantities
Scaled741SludgeDrums = Ceil(Inv40x40_741SludgeDrums * ScaleFactor);
Scaled742SludgeDrums = Ceil(Inv40x40_742SludgeDrums * ScaleFactor);
Scaled743SludgeDrums = Ceil(Inv40x40_743SludgeDrums * ScaleFactor);
Scaled744SludgeDrums = Ceil(Inv40x40_744SludgeDrums * ScaleFactor);
Scaled745SludgeDrums = Ceil(Inv40x40_745SludgeDrums * ScaleFactor);
ScaledGraphiteDrums = Ceil(Inv40x40_GraphiteDrums * ScaleFactor);
ScaledCombustibleDrums = Ceil(Inv40x40_CombustibleDrums * ScaleFactor);
ScaledNoncombustibleDrums = Ceil(Inv40x40_NoncombustibleDrums * ScaleFactor);
ScaledEmptyDrums = Ceil(Inv40x40_EmptyDrums * ScaleFactor);
//Total Drums
```

```
NonEmptyDrumsInPit = Scaled741SludgeDrums + Scaled742SludgeDrums + Scaled743SludgeDrums + Scaled744SludgeDrums +
Scaled745SludgeDrums +
  ScaledGraphiteDrums + ScaledCombustibleDrums + ScaledNoncombustibleDrums;
TotalDrumsInPit = NonEmptyDrumsInPit + ScaledEmptyDrums;

//Remap from Scaled, by combining
RemappedSludgeDrums = Scaled741SludgeDrums + Scaled742SludgeDrums + Scaled743SludgeDrums + Scaled744SludgeDrums +
Scaled745SludgeDrums; //combine all sludges
RemappedGraphiteDrums = ScaledGraphiteDrums;
RemappedCombustibleDrums = ScaledCombustibleDrums;
RemappedNoncombustibleDrums = ScaledNoncombustibleDrums;
RemappedDrumFragments = TotalDrumsInPit; //drum fragments

//Waste Calcs
NewWasteVolumePerDrum = WasteScoopSize * ScoopsPerDrum;
UndisturbedWasteLayerVolume = IntegratedVolumeWasteLayer;
If (WasteThickness<>0) // Set WasteThickness to 0 to consider only overburden
{UndisturbedWasteVolume = NonEmptyDrumsInPit * OriginalWasteVolumePerDrum;} //for use on block table
else {UndisturbedWasteVolume = 0;}
UndisturbedInterstitialVolume = UndisturbedWasteLayerVolume - UndisturbedWasteVolume;
InterstitialExpansionFactor = SoilExpansionFactor;
RetrievedInterstitialVolume = UndisturbedInterstitialVolume * InterstitialExpansionFactor/100;
TotalInterstitialScoops = Ceil(RetrievedInterstitialVolume / WasteScoopSize);
SludgeScoops = Ceil(RemappedSludgeDrums * OriginalWasteVolumePerDrum * SludgeExpansionFactor/100)/WasteScoopSize;
GraphiteScoops = Ceil(RemappedGraphiteDrums * OriginalWasteVolumePerDrum * GraphiteExpansionFactor/100)/WasteScoopSize;
CombustibleScoops = Ceil(RemappedCombustibleDrums * OriginalWasteVolumePerDrum *
CombustibleExpansionFactor/100)/WasteScoopSize;
NoncombustibleScoops = Ceil(RemappedNoncombustibleDrums * OriginalWasteVolumePerDrum *
NoncombustibleExpansionFactor/100)/WasteScoopSize;
RetrievedWasteVolume = OriginalWasteVolumePerDrum * (RemappedSludgeDrums * SludgeExpansionFactor/100 +
        RemappedGraphiteDrums * GraphiteExpansionFactor/100 + RemappedCombustibleDrums * CombustibleExpansionFactor/100 +
                RemappedNoncombustibleDrums * NoncombustibleExpansionFactor/100);
TotalWasteScoops = SludgeScoops + GraphiteScoops + CombustibleScoops + NoncombustibleScoops;
TotalWasteLayerScoops = TotalInterstitialScoops + TotalWasteScoops;
InterSoilDrums = Ceil(TotalInterstitialScoops / ScoopsPerDrum);
If (TotalDrumsInPit<>0)
{FragmentRate = TotalWasteLayerScoops / TotalDrumsInPit;}
else {FragmentRate = 0;}

//Turn drum inventory into batches, using expansion factors
//and drum fill factors and assign to initValues
PokeOverburdenSacks = OverburdenSoilSacks;
PokeInterstitialDrums = InterSoilDrums;
PokeSludgeDrums = Ceil(SludgeScoops / ScoopsPerDrum);
PokeGraphiteDrums = Ceil(GraphiteScoops / ScoopsPerDrum);
PokeCombustibleDrums = Ceil(CombustibleScoops / ScoopsPerDrum);
PokeNoncombustibleDrums = RemappedNoncombustibleDrums; //noncombustible debris
Total55GDrums = PokeSludgeDrums + PokeGraphiteDrums + PokeCombustibleDrums + PokeInterstitialDrums;
Total85GOverpacks = Ceil(RemappedDrumFragments / DrumFragsPer85) + RemappedNoncombustibleDrums;
Poke85GDrumsOfFrags = Total85GOverpacks - PokeNoncombustibleDrums; //85-gal overpacks filed with drum fragments and metal debris
MetalObjectsPerScoop = Ceil(MetalObjectsPerNoncombDrum / ScoopsPerDrum); //number of metal objects in a noncombustible debris drum
TotalOutliers = Ceil((OutlierProb/100) * ScaledCombustibleDrums);
TotalContainers = OverburdenSoilSacks + Total55GDrums + Total85GOverpacks;
```

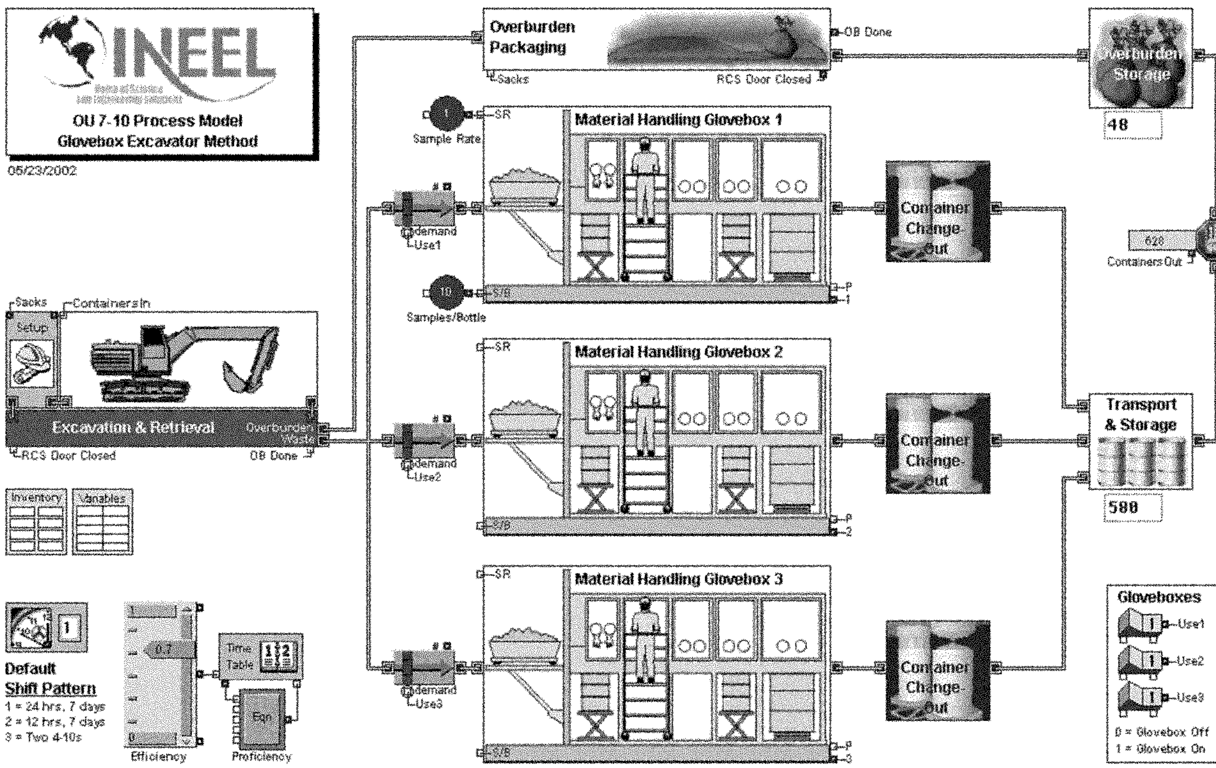
Visual Basic™ Code in Excel™

```
Sub Integrate()
'
' Macro recorded 11/05/01 by Danny L. Anderson
'
   Dim pi
   pi = 4 * Atn(1)

  ' Get needed values from spreadsheet cells
   WasteThickness = Worksheets("Calcs").Cells(7, 2).Value
   FanRadius = Worksheets("Calcs").Cells(4, 2).Value
   FanAngle = Worksheets("Calcs").Cells(5, 2).Value

  ' Convert degrees to radians
   FanAngle = FanAngle * pi / 180
   AngleRepose = (pi / 180) * Worksheets("Calcs").Cells(12, 2).Value

  ' Set maximum depth reached (MaxDepth), based on angle of repose.
  ' May not reach bottom of waste layer if angle of repose is too shallow.
   If FanRadius - 2 * WasteThickness / Tan(AngleRepose) < 0 Then
    MaxDepth = Tan(AngleRepose) * FanRadius / 2
    Else: MaxDepth = WasteThickness
    End If

  ' Integrate (i.e., partition and sum) waste layer shape to get volume
   Area = 0
   IntegratedVolumeWasteLayer = 0
   dh = 0.001
   For h = 0 To MaxDepth Step dh
      a = h / (Tan(AngleRepose) * Sin(FanAngle / 2))
      c = FanRadius - h / Tan(AngleRepose)
      X = (a / c) * Sin(FanAngle / 2)
      E = FanAngle - 2 * Atn(X / Sqr(-X * X + 1)) ' Asin(X) = Atn(X / Sqr(-X * X + 1))
      Area = ((c ^ 2) / 2) * (Sin(FanAngle) * (1 - Cos(E)) / (1 - Cos(FanAngle)) + (E - Sin(E)))
      IntegratedVolumeWasteLayer = IntegratedVolumeWasteLayer + dh * Area
   Next h
   If MaxDepth < WasteThickness Then Area = 0

  ' Send calculated values to spreadsheet cells
   ActiveSheet.Unprotect
   Worksheets("Calcs").Cells(19, 2).Value = IntegratedVolumeWasteLayer
   Worksheets("Calcs").Cells(11, 2).Value = MaxDepth
   Worksheets("Calcs").Cells(14, 2).Value = Area
   ActiveSheet.Protect

End Sub
```

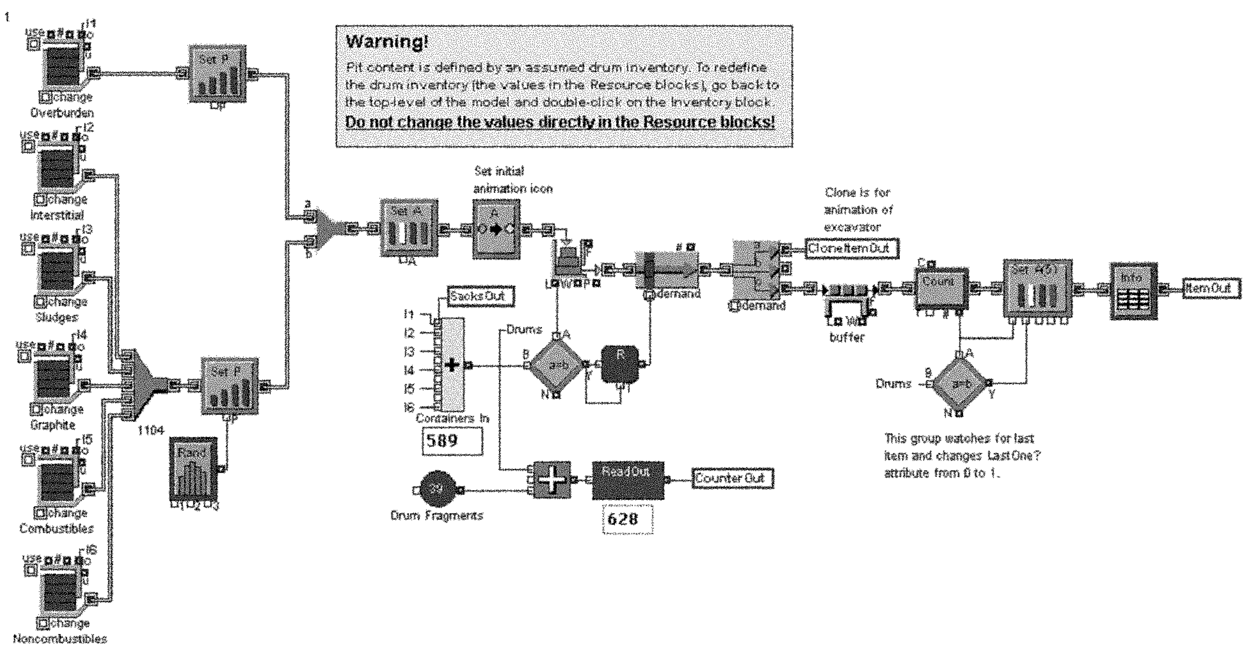
Appendix C

Screen Shots

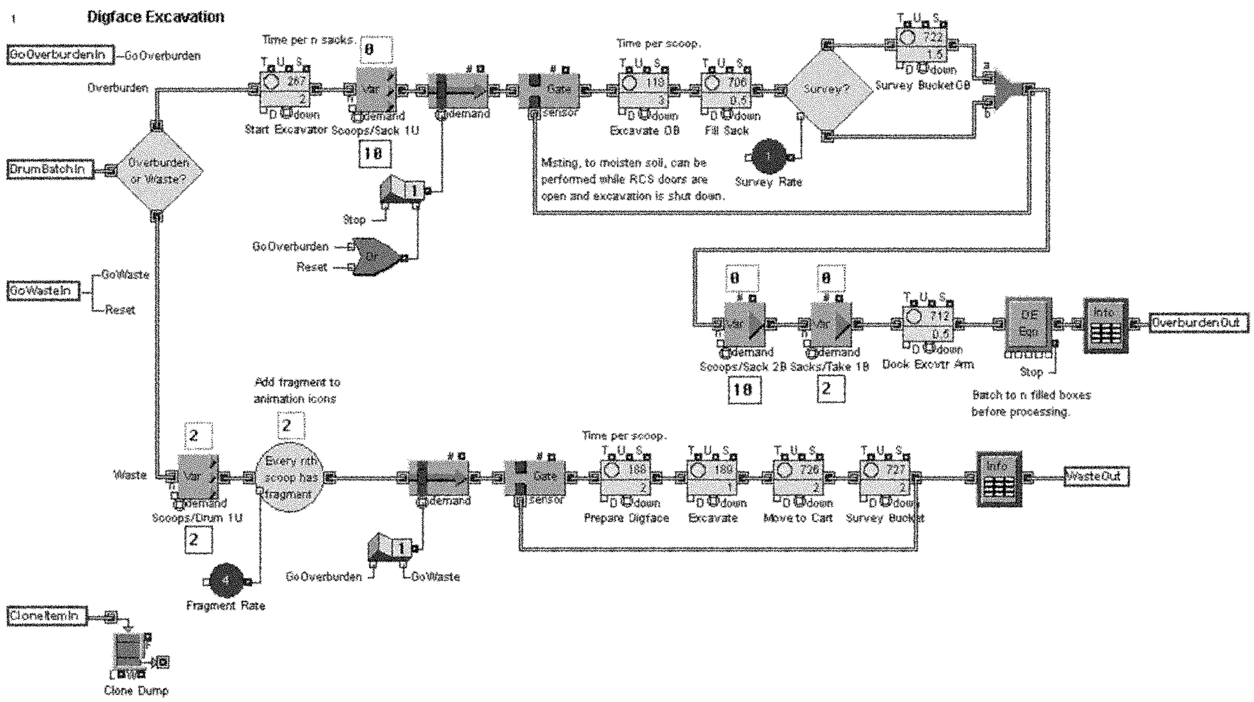
Main Module



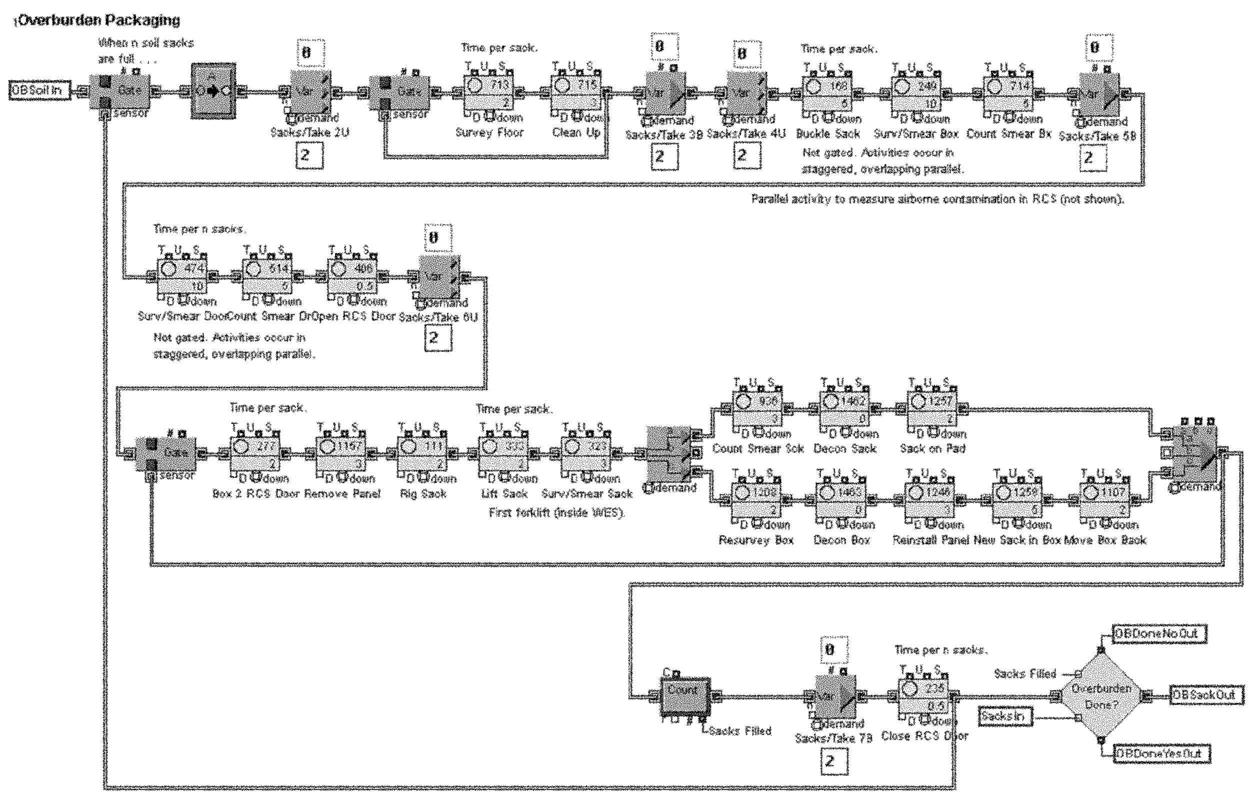
Setup Module



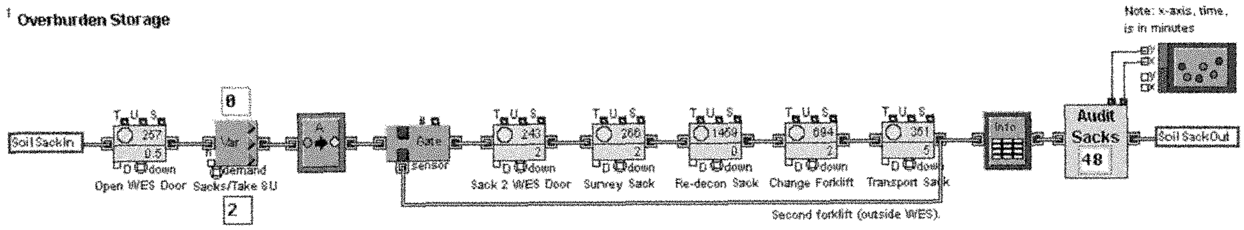
Excavation & Retrieval Module



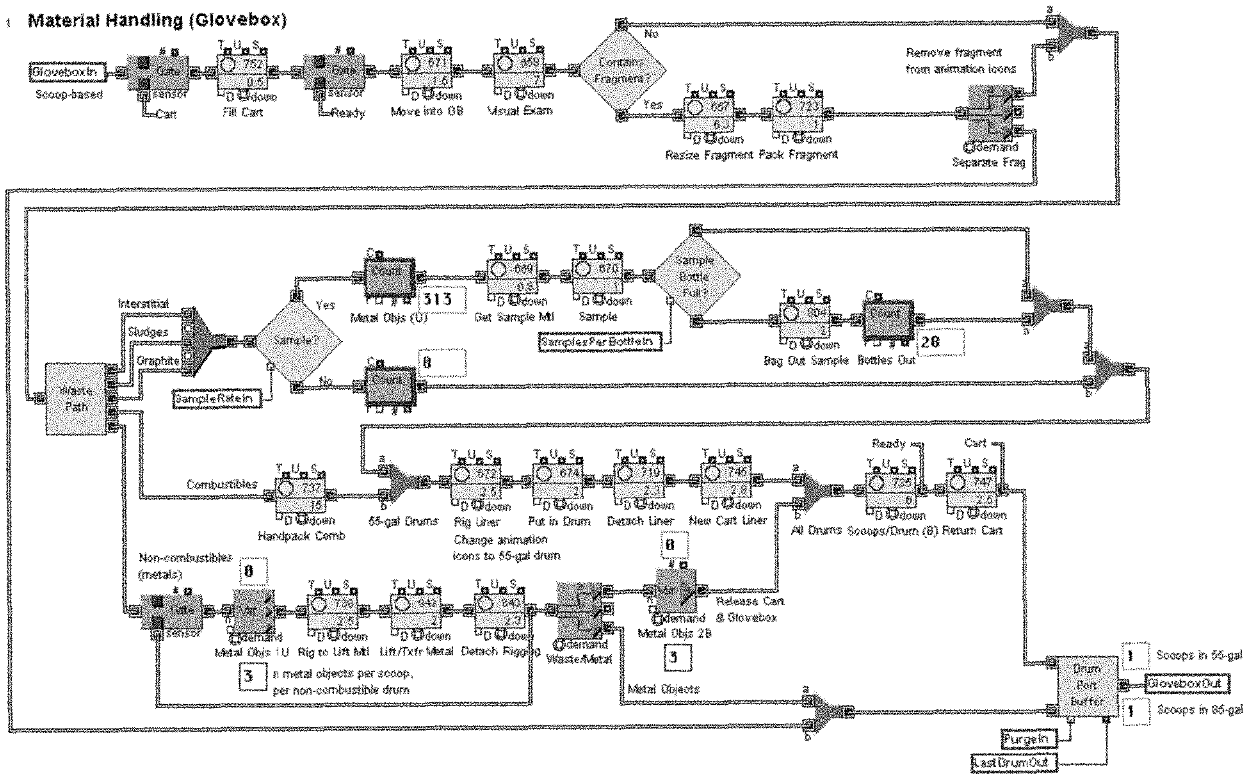
Overburden Packaging



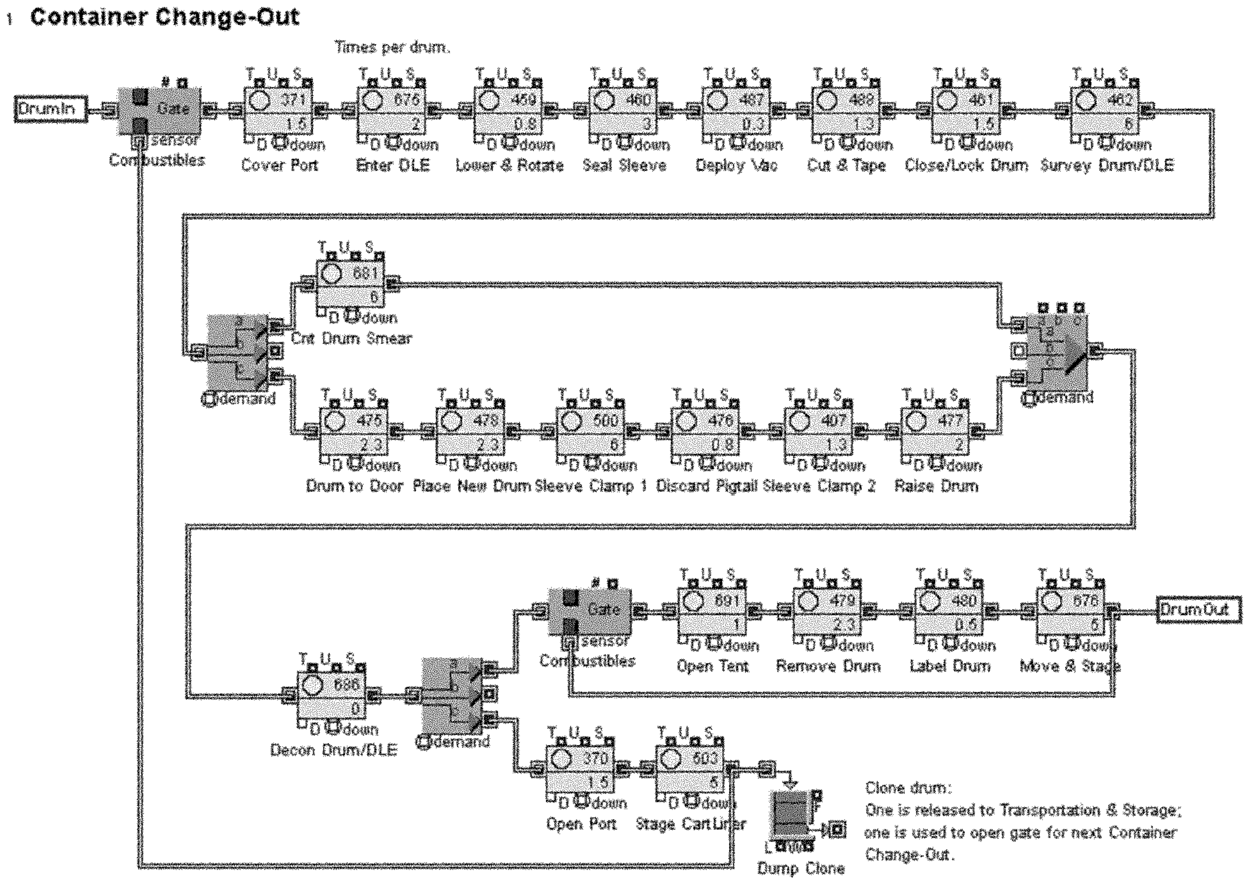
Overburden Storage Module



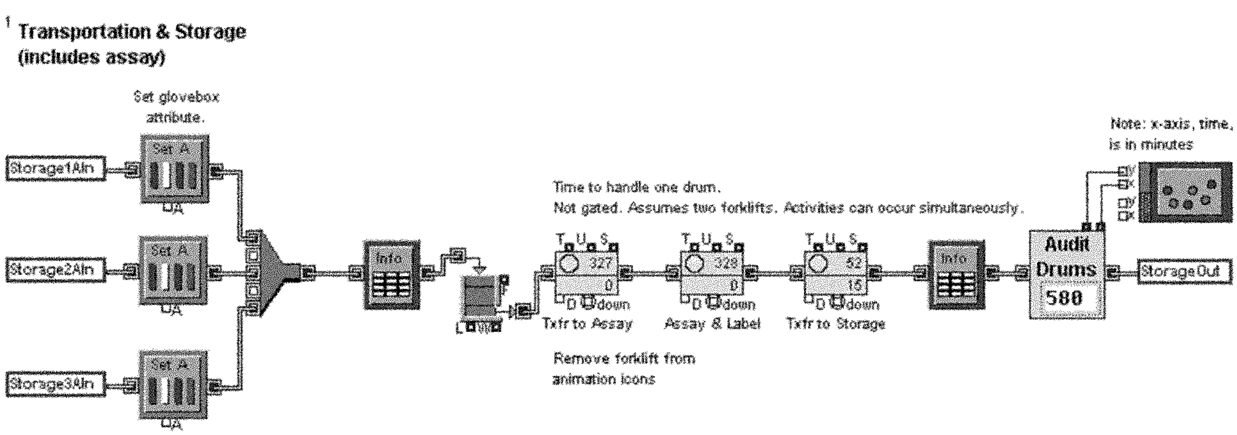
Material Handling Module



Container Change-Out Module



Transportation and Storage Module



Appendix D

Timesheet Transcripts for Model Validation

Table D-1. Timesheet transcript for Nevada Test Site video

Start	Stop	Activity	Comments	Duration	CD
10:26:26	10:27:25	No visible activity of interest		0:00:59	1
1. Prepare Full Waste Drum for Repackaging					
10:27:25	10:27:52	Loosen nut on lid ring		0:00:27	1
10:27:52	10:28:47	Tape bolt/nut	Protect sleeve from getting cut	0:00:55	1
10:28:47	10:29:35	Pull sleeve over waste drum	Notice bunjee cord in top of sleeve	0:00:48	1
10:29:35	10:31:04	Tape sleeve to waste drum		0:01:29	1
10:31:04	10:33:42	Move the drum lift and harness into place and attach drum		0:02:38	1
10:33:42	10:35:30	Lift waste drum, move to glovebox, align, and brace	Notice support brace as backup for hydraulic lift	0:01:48	1
10:35:30	10:45:19	Don respirators		0:09:49	1
2. Connect Waste Drum to Glovebox Input Port					
10:45:19	10:45:56	Remove locking band on previous sleeve, at input port, and pull back sleeve		0:00:37	1 & 2
10:45:56	10:46:04	Survey hands		0:00:08	2
10:46:04	10:47:00	Pull new sleeve over old sleeve and secure locking band to input drum port		0:00:56	2
10:47:00	10:47:40	Pull excess sleeve bag down around waste drum and secure w/ tape	Taped to prevent excess bag from getting sucked into glovebox	0:00:40	2
10:47:40	10:47:54	Don gloves in glovebox and remove blocking bar from input drum port	Blocking bar prevents pigtail from interfering or being pulled off	0:00:14	2
10:47:54	10:48:06	Pull pigtail from previous sleeve off of input drum port and into glovebox		0:00:12	2
10:48:06	10:48:37	Move waste drum forward into drum port and re-brace the lift		0:00:31	2
3. Connect Empty Drum to Glovebox Output Port					
10:48:37	10:49:20	Remove locking band on previous sleeve, at output port, and pull back sleeve		0:00:43	2
10:49:20	10:49:36	Survey hands		0:00:16	2
10:49:36	10:49:50	Raise new, empty drum towards output port		0:00:14	2
10:49:50	10:50:04	Pull new sleeve over old sleeve and secure locking band to output drum port		0:00:14	2
10:50:04	10:50:20	Survey hands		0:00:16	2
10:50:20	10:50:36	Secure locking band to output drum port		0:00:16	2
10:50:36	10:51:44	Pull excess sleeve down around drum & raise drum to final position		0:01:08	2
10:51:44	10:51:54	Install floor jack under scissors lift to secure	Backup to hydraulic lift	0:00:10	2
10:51:54	10:52:05	Survey hands		0:00:11	2
10:52:05	10:52:35	Tape excess sleeve to clean, empty drum		0:00:30	2
10:52:35	10:53:16	Survey hands, feet, and face		0:00:41	2
10:53:16	10:55:05	Doff respirators and don headphones		0:01:49	2
4. Open Waste Drum and Stash Lids					
10:55:05	10:56:20	Don gloves at glovebox and perform minor housekeeping	Leather overgloves used to protect the gloves	0:01:15	2
10:56:20	10:56:45	Remove tape from bolt/nut on locking ring on waste drum lid, at input drum port		0:00:25	2
10:56:45	10:58:15	Oil and connect pneumatic tools		0:01:30	2
10:58:15	10:58:34	Remove nut from waste drum lid locking ring, using pneumatic driver		0:00:19	2
10:58:34	10:58:50	Remove locking ring from waste drum lid and place under tray	Space under trays used to store tools & materials	0:00:16	2
10:58:50	10:59:36	Remove waste drum lid		0:00:46	2
10:59:37	10:59:57	Remove vent from waste drum lid and place under tray		0:00:20	2
10:59:57	11:01:15	Remove waste drum liner lid and place under tray		0:01:18	2
5. Empty Drum Contents					
11:01:15	11:04:10	Pull waste drum liner bag, cut open, and cut open two more layers of bags	Notice safety utility knife	0:02:55	2
11:04:10	11:12:25	Transfer waste from bag to tray, removing lids from all bottles		0:08:15	3
6. Load Waste into Empty Drum					
11:12:22	11:12:25	Don gloves at glovebox, at output drum port		0:00:03	3
11:12:25	11:12:45	Remove pigtail left from previous filled drum, at output drum port		0:00:20	3
11:12:45	11:13:20	Leave glovebox, zero-out drum scale (for weight), return to glovebox		0:00:35	3
11:13:20	11:13:25	Don gloves at glovebox, at output drum port		0:00:05	3
11:13:25	11:23:40	Transfer waste from tray into new drum	Grappler reach tools is commercially available. Tamping tool is piece of pipe w/ duct tape ends	0:10:15	3
7. Disconnect Emptied Waste Drum from Glovebox Input Port					
11:23:40	13:31:40	Lunch Break & donning respirators		2:08:00	3
13:31:40	13:32:00	Pull drum back at input drum port. and install blocking bar over port, inside glovebox		0:00:20	3
13:32:50	13:33:30	Pull drum back with [illegible] drum lift and brace, stretching/exposing [illegible] ss sleeve		0:00:40	3
13:33:30	13:34:30	Twist and tape sleeve between emptied drum and input drum port		0:01:00	3
13:34:30	13:34:40	Position mini-HEPA vacuum	Provides local ventilation while cutting sleeve. Notice all tape re-staged for quick usage.	0:00:10	3
13:34:40	13:35:35	Cut sleeve and tape ends of pigtails		0:00:55	3
13:35:35	13:36:06	Survey hands, pigtails, and vacuum		0:00:31	3

Table D-2. Timesheet transcript for glovebox mockup time and motion studies.

Start	Stop	Delta	Time (min)	Model (min)	Activity
					Place 2.5 ft^3 of sand and rock salt mix and the batteries in the lined cart. Bury the batteries in different locations. For the first cartload only, include a drum fragment (or large piece of metal to simulate a fragment).
					Start clock.
10:47:57	10:49:03	0:01:06	1.10	1.50	1. Move cart into glovebox (screw-drive).
10:49:03	10:55:10	0:06:07	6.12	6.25	2. Size drum fragment (or metal piece simulating one) using Sawzall, shears, and a nibbler, and place pieces through other drum port.
10:55:10	11:01:57	0:06:47	6.78	7.00	3. Rake through cart using long-reach trowel, fork, cultivator, hoe, etc. to find batteries. Place batteries in drum and make entry in log for each one.
11:01:57	11:03:30	0:01:33	1.55	1.75	4. Sample waste by taking ___ spoonfuls and place them in a bottle.
11:03:30	11:04:30	0:01:00	1.00	1.00	5. (First cartload only) Make an entry in the log to tie the sample to the drum.
11:04:30	11:05:45	0:01:15	1.25	2.00	6. (First cartload only) Decontaminate and bag out sample bottle. If there is no French Can, then simulate. (Timed the next day, off video.)
11:05:45	11:08:08	0:02:23	2.38	2.50	7. Rig cart liner for lifting
11:08:08	11:10:02	0:01:54	1.90	2.00	8. Lift cart liner with hoist and lower into drum
11:10:02	11:12:15	0:02:13	2.22	2.25	9. Detach rigging from cart liner
11:12:15	11:13:40	0:01:25	1.42		10. Clean up the glovebox, transfer cart, hoist chain and hook, and tools. All of the materials (e.g., wipes) used to cleanup both the equipment and the sample bottle are placed in the open drum.
11:13:40	11:16:20	0:02:40	2.67	2.75	11. Install a new cart liner in cart.
11:16:20	11:18:48	0:02:28	2.47	2.50	12. Send cart out of glovebox (screw-drive).
					(First cartload only) Stop clock and go to beginning; repeat once, without the drum fragment.
		0:30:51	30.85	33	Sum
					1. Cover drum porthole with the porthole cover. (Use chain hoist if necessary.)
					2. Close and inspect the drum loadout enclosure (DLE) and verify ventilation. Post airborne radiation area (ARA) sign.
11:31:15	11:32:00	0:00:45	0.75	0.75	3. Lower and rotate the drum, twisting the bag liner until tight.
11:32:00	11:34:50	0:02:50	2.83	3.00	4. Seal bag by placing clamps in two places on the twisted bag liner.
					5. Deploy the local HEPA vacuum. (For the time and motion studies, a small Shop Vac will do, or simulate.)
11:34:50	11:36:00	0:01:10	1.17	1.25	6. Cut bag and tape ends. Simulate scanning the bag ends for contamination.
11:37:43	11:39:10	0:01:27	1.45	1.50	7. Place lid on drum and secure locking ring.
					8. Simulate surveying and smearing drum (10 smears). Pass the smears out of the enclosure.
					9. Simulate surveying and smearing the DLE for stray contamination. (10 smears) Pass the smears out of the enclosure.
11:39:10	11:41:15	0:02:05	2.08	2.25	10. Move drum near door of the DLE.
			2.08	2.25	11. Move the second, new drum into place. (Assume same as #10.)
11:43:15	11:47:20	0:04:05	4.08	6.00	12. Loosen clamp, lower pigtail, and attach the new bag to the drum port over the old pigtail with the first sleeve clamp.
11:47:20	11:48:00	0:00:40	0.67	0.75	13. Remove the old bag stub or pigtail from the previous bag and drop it into the new drum.
11:46:09	11:47:20	0:01:11	1.18	1.25	14. Attach the second sleeve clamp. (Time is subset of #12.)
11:48:00	11:50:00	0:02:00	2.00	2.00	15. Raise the drum up into final position and pull the excess bag down around the drum.
					16. Open the DLE.
			2.08	2.25	17. Attach drum handler to drum and move drum out of the DLE. (Assume same as #10.)
					18. Affix and annotate a label on the drum. Log info in logbook.
				5.00	19. Move drum to staging area (~ 50 feet away) to await for transportation. (At least as long as #10.)
					20. Open the drum port by removing the cover, from inside the glovebox. (Use chain hoist if necessary.)
					21. Remove the new cart liners and sampling materials from the drum and stage them in the glovebox.
					Stop clock.
		0:16:13	20.38	28.25	Sum

Appendix E

Glovebox Design Alternatives Analysis

Overview

The OU 7-10 Glovebox Excavator Method Process Model was used to compare the schedule durations associated with four different glovebox designs. The model indicated that among the four designs, the greatest reduction in schedule would be only about 13%. This appendix documents: (1) the design alternatives, (2) how the model was used to support the trade study, and (3) the design selection. It should be noted that the absolute times (in days) mentioned here are associated with the then-current state of process development and understanding, which has changed significantly.

The original concept (see Figure E-1) had the glovebox elevated approximately 84in. above grade to allow unimpeded access for drum bag-in bag-out operations. The waste examination station was straddled by the two 55-gal load-out ports with the 85-gal port located near the far end of the glovebox. No enclosure surrounded the drum bagging area. The operators accessed the different stations with a small moveable work platform, with stairs, approximately 58 in. above grade. This positioned the operators' hands above the glovebox floor level but at the transfer cart height. The conceptual design incorporated three separate hard-sided enclosures underneath the glovebox floor plan. The first modification made the enclosures soft-sided and collapsible to allow the operator to position his moveable work platform along the glovebox. This was the configuration when the brainstorming session took place and is considered the baseline configuration for this effort.

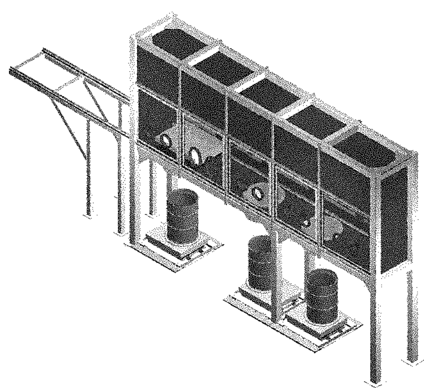


Figure E-1. Baseline glovebox design.

During process development meetings, this design was challenged as being ergonomically difficult to use and as potentially having a negative impact on the schedule. Four alternative conceptual designs were developed and evaluated based on schedule impacts, materials costs, and human factors.

Design Alternatives

Alternative 1 (see Figure E-2). For this design, the glovebox floor elevation remained at 84 in. The load-out port configuration remained the same as the baseline. But the wall of the drum change-out enclosure was expanded beyond the glovebox wall by about 40 in. along the full length of the glovebox, except at the examination station. The enclosure was divided into three separate sections to isolate the load-out areas. A set of permanent stairs provided operator access to the examination station. Platforms were placed above the enclosures, which remained soft-sided but were now fixed (noncollapsible). Both sides of the glovebox were identical. Inside the glovebox, access to the load-out ports from the new platform position only could be accomplished with long handled tools. A variation to this design (1A) was considered, in which the work platform on one side only was made continuous at the 58 in. elevation allowing the operator access to the entire length of the glovebox floor.

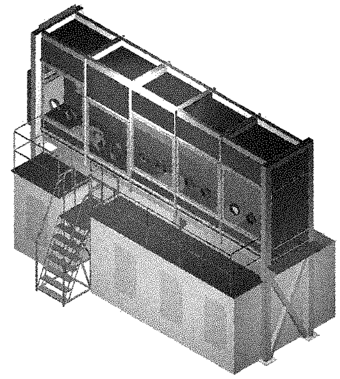


Figure E-2. Glovebox design alternative 1.

Alternative 2 (see Figure E-3). This design had the cart and rail assembly lowered so operator access could be off the floor. This moved the examination station and the second cart next to the Retrieval Confinement Structure (RCS) interface. The three load-out ports remained at the 84 in. elevation and were strung out to the end of the glovebox. This put a step in the glovebox that required everything to be rigged to load into a drum. The load-out enclosure extended along the length of the load-out portion and beyond the glovebox wall, with a platform above the extended enclosure wall. Both sides of the glovebox were identical. Access to the platforms would be by stairs from the end of the glovebox. The enclosure was a single unit, with no individual compartments. A variation to this design (2A) was considered, in which the enclosure wall on one side was removed and the platform on that side lowered to an elevation of approximately 58 in., to allow operator access to the glovebox floor level along the drum load-out stations.

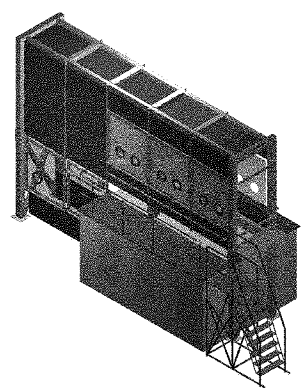


Figure E-3. Glovebox design alternative 2.

Alternative 3 (see Figure E-4). This design took configuration 2A and raised the examination stations back up to the same 84 in. elevation, as the load-out ports. This left the enclosure flush on the one side with the platform continuous along the length of the glovebox at about 58 in. All the above configurations, using a continuous platform, had it on the right side of the glovebox looking into the RCS. This design moved it to the left side so that a right-handed operator generally would be moving to his right to complete his tasks. On the other side, the platform is stepped 58in. at the examination stations and 84in. above the enclosure at the load-out stations. The enclosure remained a single unit for all three load-out ports.

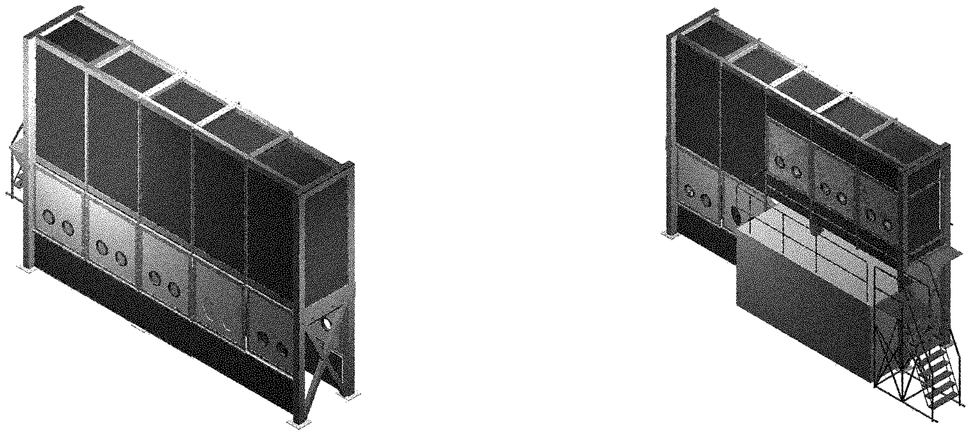


Figure E-4. Glovebox design alternative 3.

Alternative 4 (see Figure E-5). All of the previous design alternatives consisted of three identical gloveboxes located equidistant from the excavator, one centered on the excavator and the other two at 45° to the left and right. All configurations use an overhead crane. The fourth design alternative involved the use of two gloveboxes to process soil and one to process debris type waste using the cart (tray) concept of either configuration 1A or 3 described above. For the soil processing glovebox a conveyor belt would deliver the soil to a single examination station located right next to the RCS interface. Operators would be positioned on either side of this station. With the load-out enclosure high enough to allow unimpeded operator access, it forced the conveyor higher than the debris glovebox floor. This became an issue for the excavator, which was required to reach higher and to two different levels. But the height of the examination section of the glovebox could have been much smaller because there would be no overhead crane to worry about. From the examination station, the soil could be diverted to one of three load-out ports at the end to the conveyor. The load-out stations were in a single hard-sided permanent enclosure accessible from the floor level.

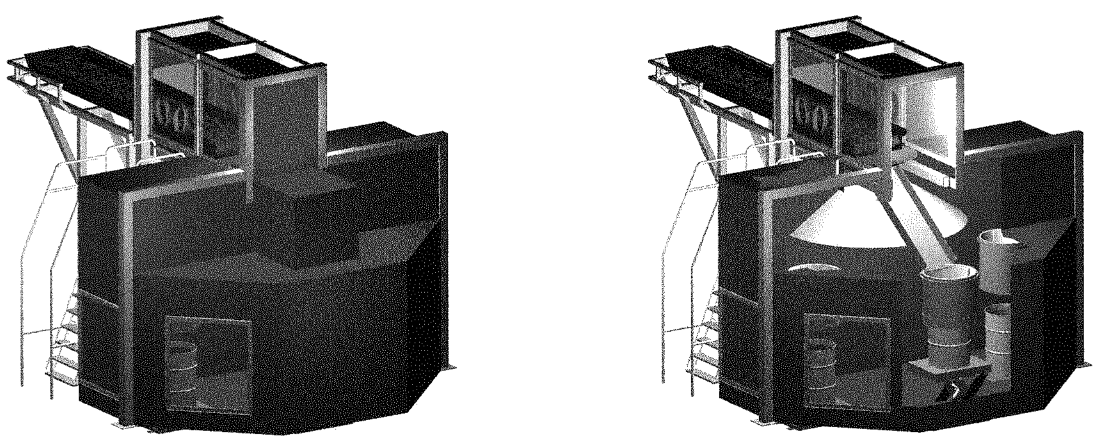


Figure E-5. Glovebox design alternative 4.

Schedule Impact Analysis with Model

Each of these designs implied a slightly different process, with different anticipated process activity times. The process model was modified and used to represent each of these designs. Activity times for the alternatives and the original baseline are compared in Table E-1. For alternatives 1 through 3, only the times had to be changed. For alternative 4, the structure of the model also had to be modified somewhat.

Table E-1. Task times for glovebox design alternatives.

Block Label	Base-line	ALT1	ALT2	ALT3	ALT4 (ALT3 GB)	ALT4 (Conveyor)
Move into GB	1.00	1.00	1.00	1.00	1.00	1.00
Visual exam	8.00	4.00	4.00	4.00	4.00	8.00
Handpack comb	15.00	15.00	15.00	15.00	15.00	0.00
Rig to lift mtl	3.00	3.00	3.00	3.00	3.00	0.00
Lift/Txfr metal	2.00	1.00	3.00	2.00	2.00	0.00
Detach rigging	2.00	2.00	4.00	2.00	2.00	0.00
Fragment to 85g	5.00	5.00	10.00	5.00	5.00	5.00
Get sample mtl	2.00	2.00	2.00	2.00	2.00	2.00
Sample	8.00	4.00	4.00	4.00	4.00	8.00
Bagout sample	6.00	5.00	5.00	5.00	5.00	6.00
Rig liner	5.00	5.00	5.00	5.00	5.00	0.00
Put in drum	2.00	2.00	4.00	3.00	2.00	0.00
Detach rigging	2.00	2.00	2.00	2.00	2.00	0.00
Install new lin	10.00	10.00	10.00	10.00	10.00	0.00
Return cart	1.00	1.00	1.00	1.00	1.00	0.00
Decon equip	5.00	5.00	7.00	5.00	5.00	0.00

A summary of the differences between the alternatives is shown in Table E-3, at the end of this appendix.

Model Results and Design Selection

Table E-2 shows the schedules associated with each design alternative.

Table E-2. Model schedule results/predictions.

	Baseline	Alternative 1 Baseline w/Continuous Platform	Alternative 2 Baseline w/2 Stations @ Grade Level	Alternative 3 Baseline w/Continuous Platform and 3 Co-located Drum Ports	Alternative 4 2 Conveyors and 1 Alternative-3 Glovebox (for Debris)
Productive Time (days)	39.1	34.05	37.9	34.7	39.3

Design alternative 3A was selected, and became the new baseline

Table E-3. Design alternatives summary.

	Changes and Rationale				
		Alternative 1	Alternative 2	Alternative 3	Alternative 4
Activity	Baseline	Baseline w/ Continuous Platform	Baseline w/ 2 Stations @ Grade Level	Baseline w/ Continuous Platform & 3 Co-located Drum Ports	2 Conveyors & 1 Alternative-3 Glovebox (for Debris)
Move cart into glovebox					
Perform visual examination of material		Reduced 50% - Eliminate climbing up/down stairs	Reduced 50% - Eliminate climbing up/down stairs	Reduced 50% - Eliminate climbing up/down stairs	Reduced 50% in glovebox – Eliminate up/down stairs
Hand pack combustibles in 55-gal drum					Reduced to 0 in conveyors – debris only in glovebox
Rig to lift noncombustible (metal debris)					Reduced to 0 in conveyors – metal only in glovebox
Transfer noncombustible debris (metal) to 85-gal drum		Reduced 50% - Don't have to move stairs	Increased 50% - Lift each item to higher elevation		Reduced to 0 in conveyors – metal only in glovebox
Detach rigging			Increased 100% - Working thru ports 4 ft above GB floor		Reduced to 0 in conveyors – metal only in glovebox

Table E-3. (continued)

Activity	Changes and Rationale				
	Baseline	Alternative 1	Alternative 2	Alternative 3	Alternative 4
		Baseline w/ Continuous Platform	Baseline w/ 2 Stations @ Grade Level	Baseline w/ Continuous Platform & 3 Co-located Drum Ports	2 Conveyors & 1 Alternative-3 Glovebox (for Debris)
Extract drum fragment and place in 85-gal drum			Increased 100% - Lift each item to higher elevation. Working thru ports 4 ft above GB floor		
Get sampling materials					
Get sample		Reduced 50% - Eliminate climbing up/down stairs	Reduced 50% - Eliminate climbing up/down stairs	Reduced 50% - Eliminate climbing up/down stairs	Reduced 50% in glovebox - Eliminate up/down stairs
Bagout sample		Reduced 17% - multi-person access provides efficiency for sample surveys	Reduced 17% - multi-person access provides efficiency for sample surveys	Reduced 17% - multi-person access provides efficiency for sample surveys	Reduced 17% in glovebox - multi-person access provides efficiency
Rig liner to lift					Reduced to 0 in conveyors – debris only in glovebox
Lift liner and place in 55-gal drum			Increased 100% - Lift each item to higher elevation. Working thru ports 4 ft above GB floor	Increased 50% - Reduced access to second drumport	Reduced to 0 in conveyors – debris only in glove
Detach rigging					Reduced to 0 in conveyors – debris only in glove
Install new liner					Reduced to 0 in conveyors – no carts
Return cart to digface					Reduced to 0 in conveyors – no carts
Decontaminate equipment			Increased 40% - Decon activities occur at two elevations		Reduced to 0 in conveyors – no carts